THE UNIVERSITY OF ALBERTA

AN ECOLOGICAL STUDY OF THE ALPINE PLANT COMMUNITIES ON SIGNAL MOUNTAIN, JASPER NATIONAL PARK

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "AN ECOLOGICAL STUDY OF THE ALPINE PLANT COMMUNITIES ON SIGNAL MOUNTAIN, JASPER NATIONAL PARK" submitted by Julia Olga Hrapko in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

A study of the major alpine plant communities on Signal Mountain was made during the summer of 1967, with some additional observations in 1968 and 1969. The study also included measurements of selected environmental factors: air and soil temperatures, solar radiation, relative humidity, precipitation, wind velocity, slope angle and aspect, elevation and other topographic features. Soil profiles were described and sampled for moisture content and retention, texture, reaction and nutrient status. Snow release dates and some phenological observations were also recorded.

Two hundred and seventy plant taxa were identified in the study area, including 158 vascular plants, 58 bryophytes and 54 lichens. Dominant growth forms of the vascular flora are described.

Twelve community types were analyzed quantitatively and 3 described subjectively. On the south slope are *Dryas* islands on scree (A), cushion plants of rock crevices (AA), *Dryas* - graminoid (B), and *Dryas* - *Kobresia* (C); *Dryas* - lichen on the ridge top; and on the north slope *Dryas* - moss (E), *Cassiope tetragona* - *Dryas* (F), *Dryas* - *Empetrum* (G), *Dryas* - *Salix arctica* (H), *Cassiope mertensiana* - *Phyllodoce glanduliflora* (J), *Salix arctica* - *Arctagrostis* - moss (K), *Salix arctica* - *Antennaria lanata* (L), *Carex nigricans* (M), *Salix nivalis* (N), and nivation hollow vegetation (O).

Inter-community relationships were shown in two ways: (1) by an arrangement of vascular species in a phytosociological table, and (2) by the construction of an ordination. The phytosociological table showed 3 main groupings of species: (a) Chionophobes and (b) Chionophiles, both having relatively narrow tolerance ranges, and (c) Alpine Constants which have wide ecological amplitudes. The two-dimensional ordination showed vegetational relationships among communities based on 3 major species: *Dryas hookeriana*, a Chionophobe, *Salix arctica*, an Alpine Constant, and *Carex nigricans*, a Chionophile. Environmental and vegetational data were plotted on the ordination and strong interrelationships were indicated.

Examples of vegetational zonations and distributional patterns on Signal Mountain were described. Vegetation along a transect crossing the main ridge was analyzed and data presented in a profile diagram of the mountain. Distributions of 39 species were plotted at 10 m intervals on the transect. *Dryas* was shown to be the overall predominant species, with *Salix arctica* co-dominant on the north slope. Fourteen of the 15 recognized community types were found on the transect, and many intermediate phases were noted.

A brief comparison of the alpine flora on Signal Mountain with those of arctic and other alpine areas showed a strong arctic influence on Signal.

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INTRODUCTION

The Rocky Mountains are the easternmost mountain system in the Canadian portion of the Western Cordillera. They extend from New Mexico, U.S.A., northwest to Yukon in Canada, and form more than half the length of Alberta's western boundary. Ecologically, most of the Canadian Rocky Mountains are generally referred to as the far northern Rockies (Daubenmire 1943), with the line between northern and far northern at about 50° latitude (Ogilvie 1962).

Little ecological work has been done in the alpine zone of the Canadian Rockies. This study of alpine plant communities on Signal Mountain was the first in Jasper National Park and the farthest north in the Rocky Mountains. Similar studies have been made only in Banff National Park (Beder 1967) to the south of Jasper, and in the Livingstone Range (Bryant 1968) south of that. Much more is known about alpine vegetation in the U.S. Rockies.

This study of alpine plant communities on Signal Mountain is part of a comprehensive ecological investigation of the vegetation of Banff and Jasper National Parks under the direction of Dr. G. H. La Roi, Department of Botany at the University of Alberta, and supported in part by the National Research Council. Most of these studies in Jasper National Park cover lower elevations: subalpine fir-Engelmann spruce forests (Beil 1966), montane and subalpine lodgepole pine forests (Hnatiuk 1969), montane Douglas fir forests

(Stringer 1966), and montane grasslands (Stringer 1969). A study of montane and subalpine black spruce forests by T. F. Laidlaw is nearing completion. The second investigation of alpine tundra in the Maligne Range, centred in the Bald Hills area, is being conducted by P. Kuchar.

The objectives of this study on Signal Mountain have been

(a) to describe, qualitatively and quantitatively, the physiognomy, vegetation structure and species composition of the major plant communities of the alpine zone; and

(b) to observe, measure and describe some of the prevailing environmental factors and to ascertain their probable influence on the development and distribution of the alpine plant communities.

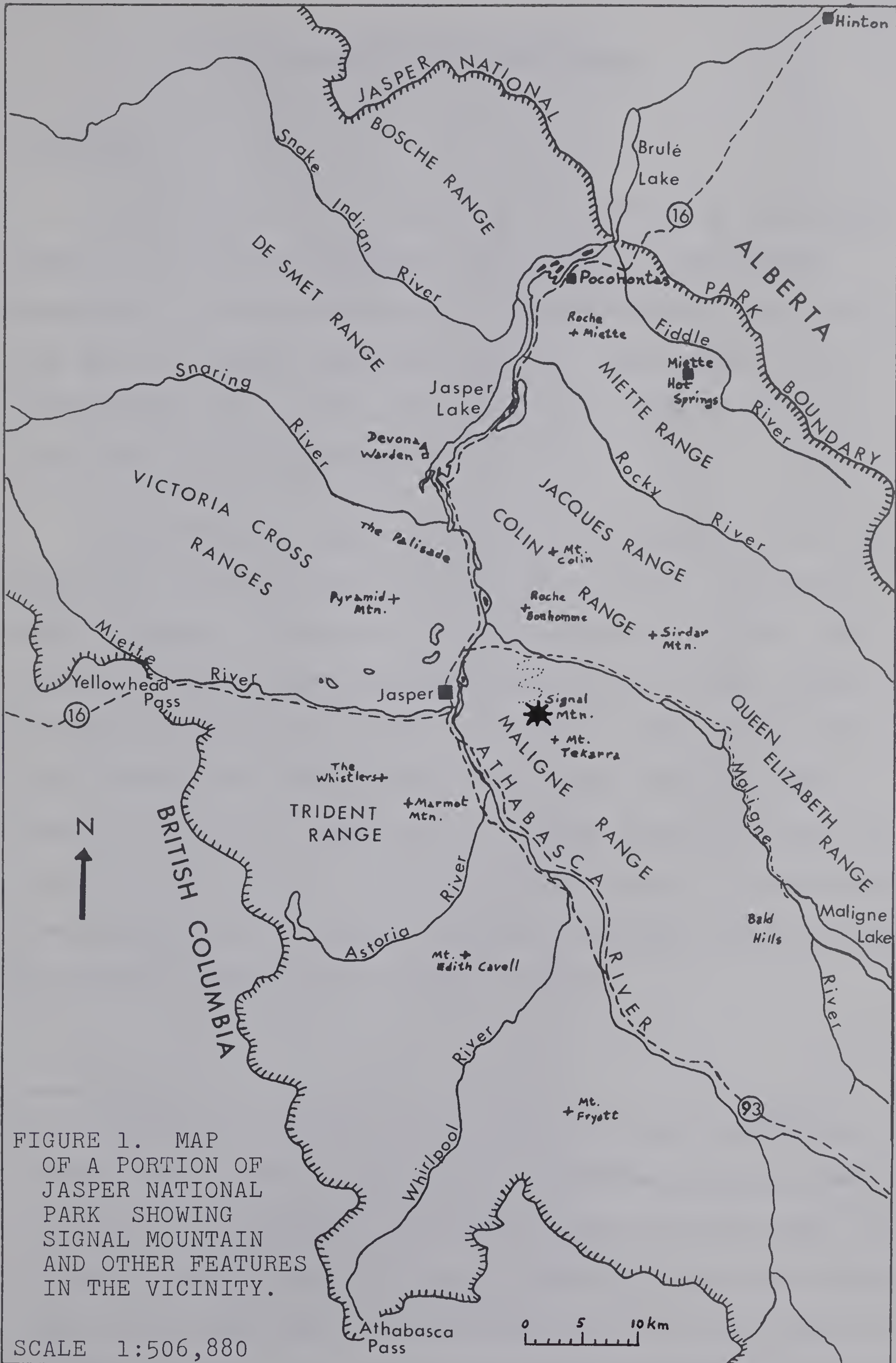

FIGURE 1. MAP OF A PORTION OF JASPER NATIONAL PARK SHOWING SIGNAL MOUNTAIN AND OTHER FEATURES IN THE VICINITY.

SCALE 1:506,880

DESCRIPTION OF STUDY AREA

Location

Signal Mountain is located at the NW end of the Maligne Range, one of the easternmost Main Ranges of the Rocky Mountains, on the E side of the broad Athabasca River valley and due E of Jasper townsite (Fig. 1). The summit is at latitude 52° 51' N, longitude 117° 59' W, and is 2311 m (7582 ft) above sea level.

The mountain's name is believed to be related* to the early fur trading history of the Jasper area. Following David Thompson's discovery of Athabasca Pass in 1811, the Athabasca River became an important part of a major route through the mountains to the west coast. Fur traders and other travellers coming downstream, after crossing the Great Divide, were signalled by a large fire built near the top of Old Fort Point, a ridge near the base of the mountain that became known as Signal (McGuire, personal communication). The name was officially adopted in 1916.

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* An alternative history of the name is given in Alberta Place Names, which states that the mountain was so named because of a telephone, presumably connected with the fire lookout, located near the top. However, since the lookout was established about 5 years after the official naming of Signal Mountain, this explanation does not appear plausible.

PLATE 1. View of Signal Mountain from the east, showing the rounded topography of the steeper south slope on the left and the more gentle north slope with its solifluction terraces on the right. The dip of the rock strata may be seen at the eastern end of the mountain, above the lake.

Jasper townsite is in the valley at extreme left centre. Pyramid Mountain and other peaks in the Victoria Cross Ranges are beyond the Athabasca River valley. The white peak in the left distance is Mount Robson, the highest in the Canadian Rockies at 3954 m (12,972 ft).

(Photographed August 25, 1967.)

The alpine zone is reached from Highway 16 *via* the Maligne River valley road and a National Park fire road, a total of 19 km (13 miles) from Jasper. During late spring, summer and early autumn a fire lookout is maintained at the upper end of this fire road, at an elevation of 2137 m (7011 ft). The Skyline Trail to Maligne Lake begins along this access road about 1 km before the lookout is reached and traverses the N and NE slopes of Signal Mountain in the upper part of the subalpine zone. The Botany Department mobile laboratory, used as field headquarters for this study, was located a short distance below the beginning of the Skyline Trail (Fig. 3).

Geology

Much of the following geological description is based on Charlesworth (personal communication) and Charlesworth *et al.* (1967).

The Main Ranges at the latitude of Jasper are separated from the Eastern Ranges by the Pyramid Thrust which skirts the lower northeastern slopes of Signal Mountain. The bedrock of Signal is Precambrian in age and belongs mainly to the lower member of the Wynd Formation. On the SW shoulder of the mountain the dip is 30° SW, but the bedding on the NE slope is complicated by folding. These factors have contributed to the development of the present topography.

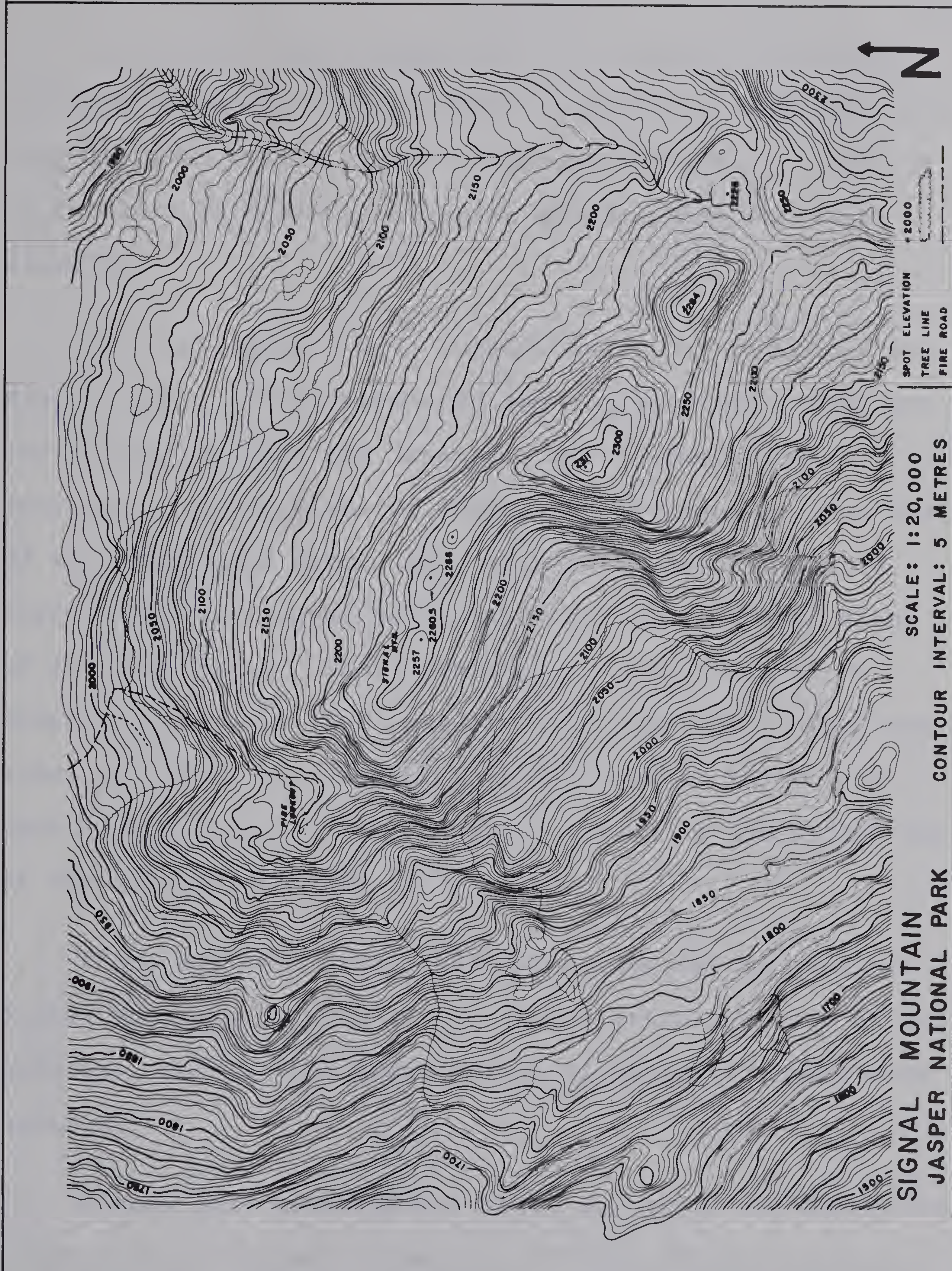


FIGURE 2. CONTOUR MAP OF SIGNAL MOUNTAIN SHOWING THE ALPINE ZONE.

Arenaceous beds predominate and form the main ridge of Signal Mountain. They consist chiefly of sandstone and conglomerate, with a little siltstone and slate. Veins of quartz with subsidiary carbonate and chloride are also present.

The argillaceous beds consist mostly of siltstone and slate, with a little sandstone and conglomerate. They are lenticular in shape and recessive due to their lesser resistance to processes of weathering and erosion than that of the arenaceous beds. As a result, several elongated depressions or troughs have formed on the northerly slope of the main ridge. These depressions trend in a SE-NW direction, more or less parallel with the ridge. They are wider at the NW end, becoming very narrow at the SE end. Each such depression is labelled a "draw" in the sketch map of the alpine zone (Fig. 3).

There has been practically no geological mapping of Signal Mountain because of (1) the relative scarcity of rock outcrops, and (2) the great amount of mixing of loose rock material.

Broken rock material has been, and still is, subjected to much mixing on all slopes due to the combined effects of frost action and gravity, resulting in various forms of patterned ground. Solifluction terraces and stone nets are prominent features of the northerly slopes, and stone stripes are common on the southerly and easterly slopes.

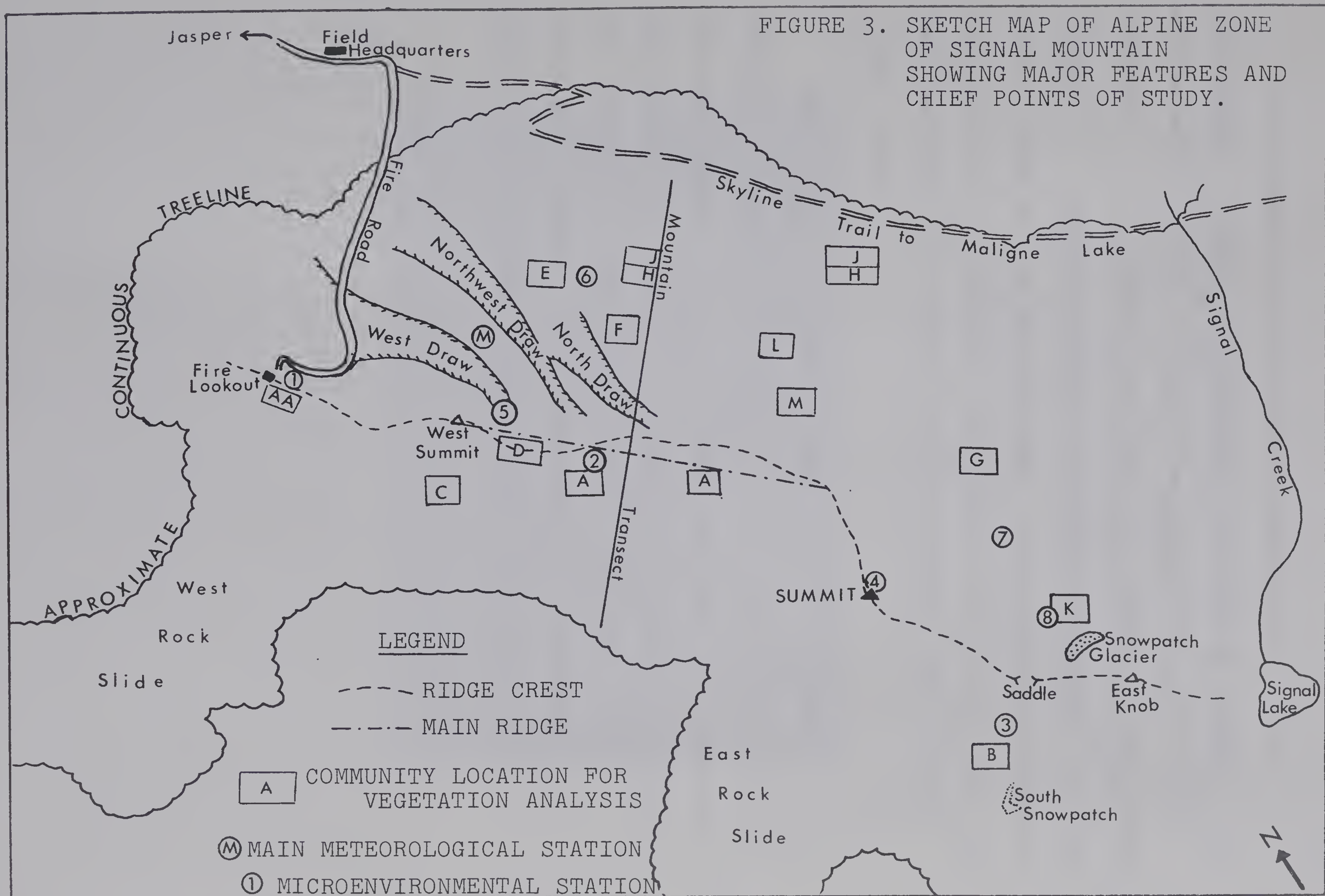


FIGURE 3. SKETCH MAP OF ALPINE ZONE OF SIGNAL MOUNTAIN SHOWING MAJOR FEATURES AND CHIEF POINTS OF STUDY.

Pleistocene glaciation has contributed to the development of many physiographic features on Signal. The entire mountain has obviously been scoured by ice action, resulting in a rounded and relatively smooth macrotopography (Plate 1). Scoured bedrock and roches moutonnées are found on the ridge and on the NW slope. A considerable amount of glacial drift is present, particularly on the NE slope, and large erratics are found on both northerly and southerly slopes (Plate 2).

More recent erosion by snow and ice is evident in the presence of nivation hollows. It was discovered later in the study period that a snowbank which had been observed and photographed at regular intervals was a snowbank glacier. Its location is shown on the sketch map (Fig. 3) and successive changes in its shape and size throughout the summer were recorded in photographs (see Plate 23).

PLATE 2. A large glacial erratic located on the S slope of Signal Mountain. The lower right portion, which faces S, has been smoothed by wind eddy erosion. (Photographed July 28, 1967).

Vegetation Zones

The lower slopes of Signal Mountain, including montane and part of the subalpine zones, have a predominant cover of *Pinus contorta*, a fire successional species. *Alnus crispa*, *Salix drummondiana* and young *Picea glauca* are common, with occasional *Populus tremuloides* and *Picea mariana* also present. According to Chief Warden F. L. McGuire (pers. comm.) a widespread fire swept through the Jasper area in the mid-1800s. From both aerial photographs and personal observations it appears that the uppermost extent of the fire was at an elevation of about 1850 m (6025 ft), since old *Abies lasiocarpa* - *Picea engelmannii* (ca. 200 to 225 years) forest begins rather abruptly around this elevation. At 2070 m (6800 feet) the trees are distinctly stunted and form spire thickets on the north slope.

The alpine zone covers an estimated 13 km^2 (5 sq. miles) on Signal Mountain. The alpine zone is usually defined rather generally as the zone above tree line. It was more exactly defined in this study as the zone above the growth of stunted trees, or krummholz with supranival leaders; within it tree species are absent or occur only as prostrate shrubs. Tree line, by this definition, is at an uppermost elevation of 2115 m (6940 feet) on the south slope and 2090 m (6860 feet) on the north, although the uppermost continuous forest line, which is shown as tree line in Fig. 2, is much lower.

METHODS AND EQUIPMENT

Comments on General Usages

The main ridge of Signal Mountain trends in a SE - NW direction so the chief slopes have SW and NE aspects. For the sake of convenience, however, they are generally referred to as S and N slopes, except where the correct aspect is of critical importance. South and north are spelled out where confusion with letters designating the plant communities might arise.

Much of the equipment used for distance measures was marked in feet and inches. Throughout this thesis the measurements are given in the metric system, with distances in feet and inches often following in parentheses. Wind speeds have been converted to km/hr, except in some Appendixed data where they are shown in miles/hour (mph).

All thermometers used in the field were marked in Fahrenheit degrees, and this temperature scale is used here.

Where only one species of a genus was found on Signal Mountain, the species name is usually not used more than once under each subheading in the text. Subspecies and variety names are omitted unless both a species type and the subspecific form occur together. The full taxonomic status of each taxon is given in Appendix I.

The term "study period" refers to the summer of 1967.

Meteorological Stations

1. Major Meteorological Station

A U.S. Weather Bureau "Cotton Region" instrument shelter was set up on the NW ridge of Signal Mountain, at an elevation of about 2200 m (7200 feet) (Fig. 3, Plate 3). The shelter was placed near the ground, with its base resting on stones so that air could circulate under it. Guy wires secured it to the ground as this exposed location received the full force of prevailing winds from the W and SW, as well as occasional winds from the N, NW and NE.

The shelter housed the following equipment:

(a) U.S. Weather Bureau type mercury maximum and alcohol minimum thermometers, mounted about 50 cm (20 in.) above the ground surface;

(b) Belfort (No. 5-594) hygrothermograph with the sensors 18 cm (7 in.) above the ground; and

(c) Moeller (No. 8700) distance thermograph with three mercury-filled sensors. Two sensors were buried in gravelly soil devoid of vegetation, one at a depth of 2 cm (0.8 in.) and the other a depth of 10 cm (4 in.). The third sensor was placed on a styrofoam shielded stand near the shelter, at a height of 135 cm (4.5 ft.) to obtain temperatures comparable with those of the Meteorogical Branch, Department of Transport.

A Belfort (Cat. No. 5-3850) recording pyrheliometer (bimetallic actinograph) was secured to the top of the instrument shelter for readings of solar radiation on a horizontal plane. The 7-day charts were later planimetered to determine the radiation, in langleys, received each day. A similar instrument was installed at Devona Warden Station, a valley location about 1040 m (3400 ft) in elevation, for purposes of comparison.

A U.S. Weather Bureau standard 8-inch rain gauge and a Belfort (No. 5-349) 3-cup totalizing anemometer were located near the fire lookout, at an elevation of 2137 m (7011 ft), at 70 cm and 200 cm above ground, respectively. The lookout operator kindly volunteered to make the anemometer readings.

Precipitation and maximum and minimum temperatures were recorded every morning. Anemometer readings were made each day at 4-hour intervals from 8:00 a.m. to 8:00 p.m., and one reading for the 12-hour period from 8:00 p.m. to 8:00 a.m. The other records were continuous.

Temperature and precipitation data were later obtained from the Jasper Meteorological office, located in the Athabasca River valley at an altitude of 1062 m (3484 ft), for comparison purposes.

PLATE 3. Major meteorological station on Signal Mountain, located at an elevation of 2200 m. A Belfort actinograph was secured to the top of the shelter. Housed within the shelter were maximum and minimum thermometers, a Belfort hygrothermograph, and a Moeller distance thermograph with 3 sensors on 6 m leads. Two of the sensors were buried near the shelter, at 2 and 10 cm depth respectively, and the third was placed on the stand to the right, 135 cm above ground.
The Miette River valley, and beyond it Yellowhead Pass (1133 m), down which air masses frequently move, are to the west, beyond the lookout (2137 m).
(Photographed August 9, 1967).

2. Microenvironmental Stations

Early in the study period eight locations were chosen on Signal Mountain for temperature measurement (Fig. 3). Each location was deemed different from each of the others in the combinations of the following factors: (a) slope aspect, (b) slope angle, (c) elevation, (d) local topography, (e) moisture, and (f) vegetation cover. Most of these microenvironmental (ME) stations, described in Table 1, were located at or near plant communities which were chosen for vegetation analysis later in the season.

A Taylor maximum-minimum thermometer (Six's type) was installed in a styrofoam and wire shelter at each location, with the thermometer bulb 18 cm above the ground surface (Plate 4). Temperatures were read every two to three days. During each visit soil temperatures at 10 cm depth were measured with a Weston dial probe thermometer in two places, one with vegetation cover and the other free of vegetation. At the same time, readings of wind speed, the average as well as the gusts, were made with a Deuta type hand-held 3-cup anemometer. All readings were from a height of 200 cm above ground as this was the height of the totalizing anemometer.

The thermometers were re-installed at the same locations in June, 1968, and readings were made atapprox-imately two week intervals from July 3 to September 3.

TABLE 1. MICROENVIROMENTAL STATIONS ON SIGNAL MOUNTAIN

STATION	SLOPE ASPECT	ELEVATION IN M (FT)	SITE DESCRIPTION
ME-1	N	2137 (7011)	Rocky ridge near fire lookout, with *Dryas* cover at base of thermometer
ME-2	SSW	2255 (7400)	On bare area in upper portion of extensive scree with *Dryas* islands (A)*
ME-3	S	2250 (7375)	Dry, stony patterned ground with *Dryas*-grass-sedge community (B)*
ME-4	-	2311 (7585)	Gravelly area in fellfield at the summit, patches of *Dryas* nearby (similar to D)*
ME-5	NW	2250 (7380)	Late snow release area at top of Northwest Draw, surrounded chiefly by *Salix nivalis* (N)*
ME-6	N	2205 (7230)	Gravelly area in well-drained region of *Dryas* hummocks and steps (E)*
ME-7	NNE	2210 (7255)	Moist, lush "riser" portion of small solifluction terrace with *Salix arctica* as cover dominant (similar to H)*
ME-8	NE	2227 (7305)	Very wet, hummocky and mossy area, near seepage spring fed by snowbank glacier above (K)*

* Plant communities

PLATE 4. Microenvironmental station ME-7, showing styrofoam-sheltered maximum-minimum thermometer surrounded by a *Salix arctica*-dominated community on the gentle "riser" portion of a small solifluction terrace on the north slope of Signal Mountain.

Soils

At least one soil pit was dug in each community at the completion of vegetation analysis. This pit was generally located at the centre of the base line. When there was a discontinuity in the ground cover, a soil pit was dug under each representative cover type. For example, in the scree areas one pit was dug in the bare scree and another under the vegetation. In addition to the quantitatively sampled communities, soils were collected from pits dug in two communities that were described subjectively.

Horizons were noted and described, and the depth of root penetration was recorded. Samples of each horizon were collected for later laboratory analyses. Upon return to field headquarters the samples were treated with a few drops of toluene and kept sealed for 24 hours to inhibit microbial growth, then were air-dried for storage.

In the laboratory, the soils were passed through a 2-mm sieve. The gravel portion was weighed and recorded as a percentage. Analyses made on the smaller than 2 mm fraction included the following:

(1) mechanical analysis for particles size was done by the Alberta Soil Survey Laboratory, using the pipette method (Toogood and Peters 1953);

(2) determinations of pH, conductivity, free lime, sodium, available nitrogen, phosphorus and potassium, by the Alberta Soil and Feed Testing Laboratory;

(3) soil moisture retention at 1/3 and 15 atmospheres tension (considered field capacity and permanent wilting point, respectively) using Soiltest 3 bar and 15 bar ceramic plate extractors;

(4) description of dry soil colour using Munsell colour charts in natural daylight.

In addition to profile samples, smaller soil samples were taken from 2.5 cm, 10 cm and 25 cm depths for determination of field moisture content. The last dates on which precipitation was received by the respective areas were recorded. These samples were weighed at field headquarters, treated with toluene and air-dried. In the laboratory, they were oven-dried to constant weight at a temperature of 105°C., and the weights recorded.

Another collection of soil samples from each site was made on August 15, 1968, after the area had had a prolonged period of intermittent rain. Treatment of these was the same as above.

Flora

Much of the first few weeks of the field season was occupied with the flora and the determination, by subjective observation, of the main kinds of communities, i.e., community types, present in the alpine zone of Signal Mountain. Voucher collections were made throughout the season.

The FLORA OF ALBERTA was used for identification and nomenclature of vascular species described by Moss (1959). For species not reported by Moss, authorities dealing with arctic floras were used: Porsild (1965), Wiggins and Thomas (1962) and Hultén (1968). Identifications were verified or corrected by Miss Madeleine Dumais with the help of Dr. J.G. Packer, Assistant Curator and Curator respectively, of the Herbarium, Department of Botany, University of Alberta. Bird's (1963, 1968) preliminary keys were used for the identification of bryophytes. Most identifications and some verifications of bryophytes and lichens, i.e., "bryoids", were made by Dr. C. D. Bird at the University of Calgary.

Phenological observations were begun on the first trip to Signal Mountain and continued throughout the study period. The records were chiefly concerned with anthesis and seed production. Dates of vernation were not usually obtained since much of the flora was not yet recognizable at this stage of its life cycle by the author. The phenological state of vascular species was usually noted

each time a circuit of the microenvironmental stations was made, and was also recorded for each community that was quantitatively analyzed at the time of sampling. The flowering status of the vascular flora was cursorily noted at two-week intervals during the summer of 1968.

Vegetation Analysis

Criteria for Sampling

Plant communities, which are referred to as "stands", were subjectively chosen for vegetation analyses on the following criteria:

(1) as representative of a community type, an abstract unit of vegetation synthesized from actual examples of communities (Oosting 1956), that was distinct from other community types (see also p. 80);

(2) relatively homogeneous in species composition;

(3) relatively homogeneous physical habitat;

(4) covering an area that was deemed of sufficient size to permit complete development of the community type and conforming to the first 3 criteria.

Stand size varied from 28 m^2 (300 ft^2) to 2800 m^2 (30,000 sq ft) because of the last three criteria. Since Signal Mountain's tundra was relatively untrodden by humans this criterion, fortunately, did not need to be considered.

Fifteen stands were chosen for quantitative analysis. These represented twelve community types. Time did not permit more replication. In addition, several other

communities were described subjectively.

Sampling Procedure

Upon choosing a stand, a presence list of vascular species and the known bryoids was made. Then, using a band chain, a base line was marked running through the centre of the longer axis of most stands. In the case of solifluction terraces, the base line was placed along the base of the terrace riser (Fig. 4). The terrace base and riser were then sampled as separate stands and are treated as such throughout this thesis.

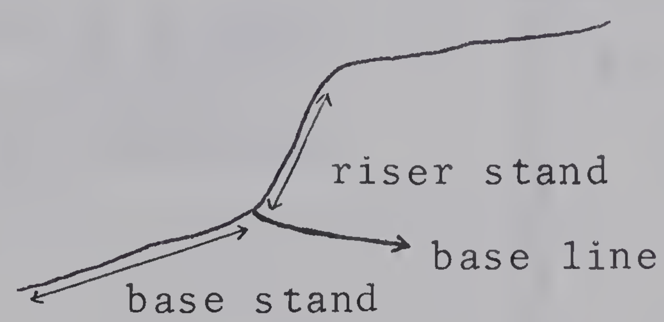


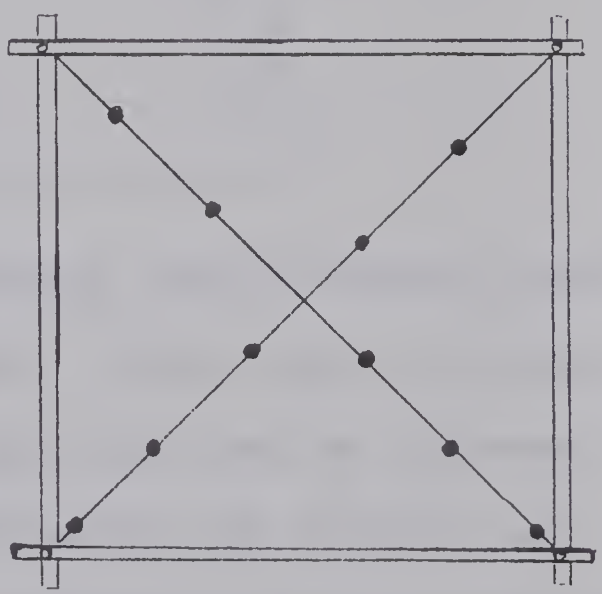
FIGURE 4. STAND DELINEATION ON SOLIFLUCTION TERRACES.

A restricted random sampling method was used. To achieve this, a second band chain was placed so that it bisected the first at right angles. In stands other than those of solifluction terraces this second line divided the stand into equal quadrants; in the terrace stands the riser and the base were each divided in half. Plots were then chosen randomly, with the use of a random numbers table, in each of the resultant quadrants or halves of each stand.

Sampling was terminated at 20 plots if all except the very rare species on the presence list were accounted for and a species-area curve would have flattened in shape (Cain 1938). If species representation was lower than expected, more plots were analyzed in each of the quadrants.

A square plot (quadrat) was used because previous plant ecological studies initiated at the University of Alberta had utilized this shape and it was considered efficient for this study (Eddleman *et al* 1964). It was thought that a standard plot shape would facilitate comparison.

FIGURE 5. DIAGRAM OF QUADRAT FRAME SHOWING THE SAMPLING POINTS USED IN VEGETATION ANALYSIS.



The sampling plots were 25 cm quadrats. A collapsible quadrat frame was constructed from screen moulding. Intersecting strings were attached to the corners and 10 points were marked on them (Fig. 5) for point sampling with a Canadian No. 14 knitting needle. All vegetation "hits" and open ground (rock, soil, etc.) were counted. In laying out the quadrat frame, one side was always placed parallel to the base line.

Cover values in each quadrat were estimated using a modification of the Braun-Blanquet Cover-Abundance scale. In calculating mean values later, the midpoint of each percentage class was used (Table 2).

TABLE 2. COVER - ABUNDANCE SCALE

SCALE NO.	PERCENTAGE CLASS	MEDIAN
6	76 - 100%	88.0
5	51 - 75	63.0
4	26 - 50	38.0
3	16 - 25	20.0
2	6 - 15	10.0
1	1 - 5	2.5
+	under 1%	0.5
R	rare	0.1

The means of both cover estimates and the cover points were expressed as percentages later. Where the two values did not agree the average of the two was used as the mean cover value for each species. Frequency (of shoots) was calculated as the percentage of quadrats in which a species was found.

Sociability, Periodicity and Vitality were also noted for each species in the quadrats. A mass collection of bryoids was made for each stand, usually from each quadrat, for later identification.

Environmental Observations

Environmental data collected at each stand at the time of vegetation analysis included:

(1) a description of local topography;

(2) a record of the elevation (later adjusted because of altimeter and map problems);

(3) a determination of the slope aspect, using a compass and correcting for a magnetic declination of 25°E;

(4) a measurement of the slope angle, using a Leupold abney level and later checking some of the stands with a Ushikata transit;

(5) a record of the various forms of rock present (e.g., boulders, scree, etc.);

(6) a record of the air temperature at 135 cm above ground at every second quadrat;

(7) a record of the soil temperature at 10 cm depth at every second quadrat, if permitted by the substrate;

(8) soil profile data and samples as described in the last section.

Mountain Transect

During the last ten days of the field season a transect of Signal Mountain, cutting the main ridge at right angles to it (see Fig. 3), was surveyed with a Ushikata transit. This transect began on the south slope at the uppermost krummholz with supranival flagging and proceeded upslope at 10°E of N for 288 m. It then continued over the top and

down the north slope for another 492 m, at which point the first supranival flag was reached on that slope. Most of the community types described for Signal Mountain earlier in the season were traversed in the total of 780 m, including, quite by accident, one of the solifluction terraces that had been sampled.

Observations along the transect included measurement of slope angles and description of topographic features at 10 m intervals. The species present within the quadrat at each 1 m interval were recorded as being dominant or merely present, while quantitative data were obtained from the 25 cm quadrat at each 10 m interval, both by cover class estimate and by cover points.

RESULTS

METEOROLOGICAL OBSERVATIONS

There are virtually no climatic records for Signal Mountain. However, 30-year normals (1931-60) for Jasper townsite are available. The 1967 Jasper data (Table 3) were compared with the Jasper normals and these general trends inferred: (1) mean temperatures were a little higher in June, almost normal in July, and much higher than normal in August; (2) rainfall was slightly higher in June and July, but much lower in August; and (3) snowfall was much higher during the preceding winter.

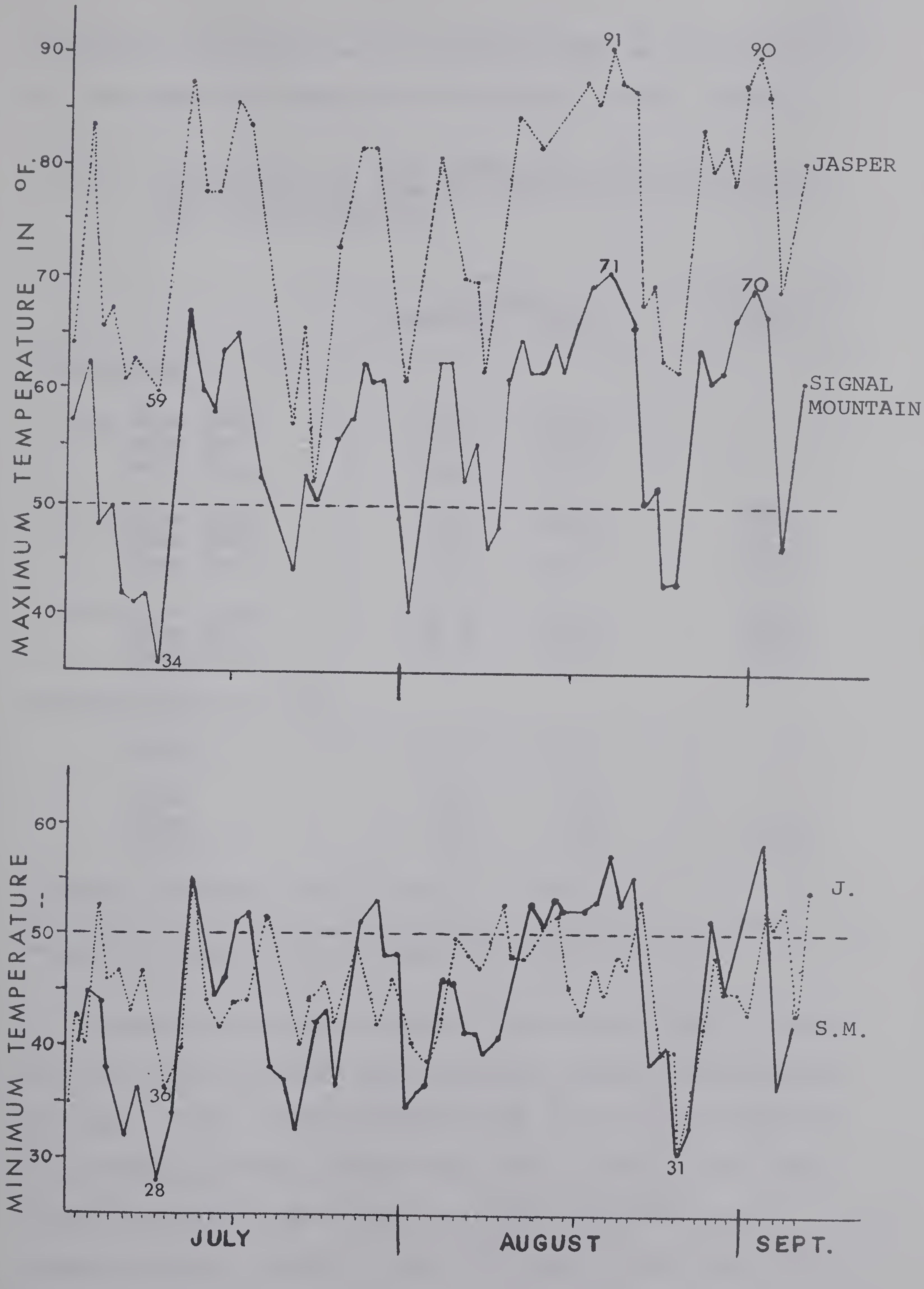
A. Temperature

1. Major Meteorological Station

Some temperature data have been recorded by fire lookout operators in late spring, summer and early autumn, but these included neither maxima nor minima. The Dept. of Transport meteorological station in Jasper is located at 1062 m (3484 ft) above sea level and thus 1138 m (3815 ft) lower than the meteorological station established at 2200 m (7200 ft) on Signal Mountain for the duration of the study period. The temperature regimes of the two stations are very different (Fig. 6, data in Appendix VI), if the lapse rate is ignored.

Maximum temperatures were consistently lower at the Signal station than at Jasper, often by 20°F. and occasionally as much as 25°. Minimum temperatures, however, were much less

FIGURE 6. COMPARISON OF MAXIMUM AND MINIMUM TEMPERATURES AT SIGNAL MOUNTAIN AND JASPER STATIONS IN 1967.



different, probably due to processes such as nocturnal cold air drainage and temperature inversions in the valley.

TABLE 3. COMPARISONS OF LONG TERM (1931-60) JASPER METEOROLOGICAL NORMALS WITH 1967 DATA AT JASPER AND SIGNAL MOUNTAIN.

	JASPER		SIGNAL MTN.
	1931-60	1967	1967
TEMPERATURE (in °F.)			
June Mean Temp.	54.2	55.9	
Mean Max.	67.0	69.6	
Mean Min.	41.4	42.3	
July Mean Temp.	59.4	58.8	49.9
Mean Max.	73.6	72.6	56.3
Mean Min.	45.2	45.0	43.5
Aug. Mean Temp.	56.8	62.4	53.4
Mean Max.	70.2	78.4	63.3
Mean Min.	43.4	46.4	43.5
PRECIPITATION (in cm)			
Annual	40.6	38.4	
June	5.5	5.6	
July	5.0	5.5	4.2
August	5.1	2.9	0.9
SEASONAL SNOWFALL (in cm)	125.0	170.7*	

*Snowfall during winter season of 1966-67.

Signal minima were usually lower than those at Jasper during colder periods, and generally higher during warmer periods. Thus minimum temperatures at the Signal station were higher than at Jasper only 30% of the days in July, when the weather was rather unstable and mostly cool. August weather, however, was much warmer and Signal had

higher minima on about 60% of the days. It may, therefore, be concluded from the 1967 data that although temperatures, particularly those of the daytime, were generally lower at the Signal station, the diurnal range on the mountain was considerably smaller than that in the valley site at Jasper.

Temperatures Above and Below the Ground Surface

Maximum and minimum temperatures 135 cm above ground (Fig. 7a, Table 4, complete data in Appendix III) fluctuated greatly, with an absolute range of 43°F. (28°-71°) during the study period. Minimum temperatures dropped below freezing three times in July and once in August. It might be noted that alpine plants other than stunted trees or krummholz do not reach this height.

Maximum and minimum air temperatures at the 50 cm and 18 cm levels were very similar and therefore only the latter are used in Fig. 7b. This similarity in readings may be partly due to a relatively unstratified microenvironment in the meteorological shelter within which the sensors of both instruments were located. The sensor for the 135 cm level was outside this shelter (see Methods, p. 13).

At 18 cm above ground temperatures ranged from 26°F. to 73°, a difference of 47° which was the greatest of all the levels measured (Fig. 7b). Minimum temperatures dropped below freezing four times in July and twice in August. Many of the alpine plants growing in relatively protected sites

FIGURE 7. MAXIMUM AND MINIMUM TEMPERATURES AT TWO LEVELS ABOVE THE GROUND SURFACE AT THE SIGNAL MOUNTAIN METEOROLOGICAL STATION IN 1967.

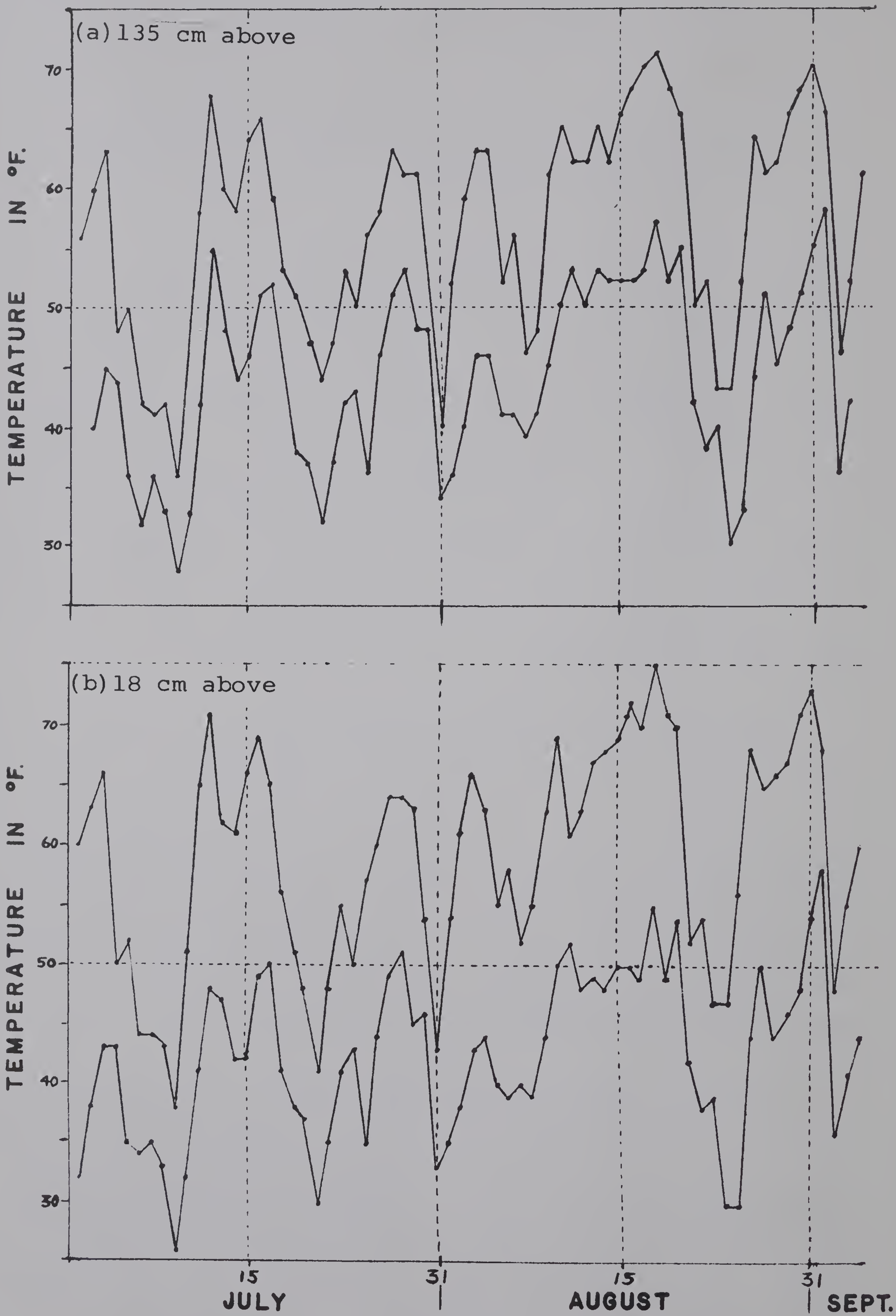
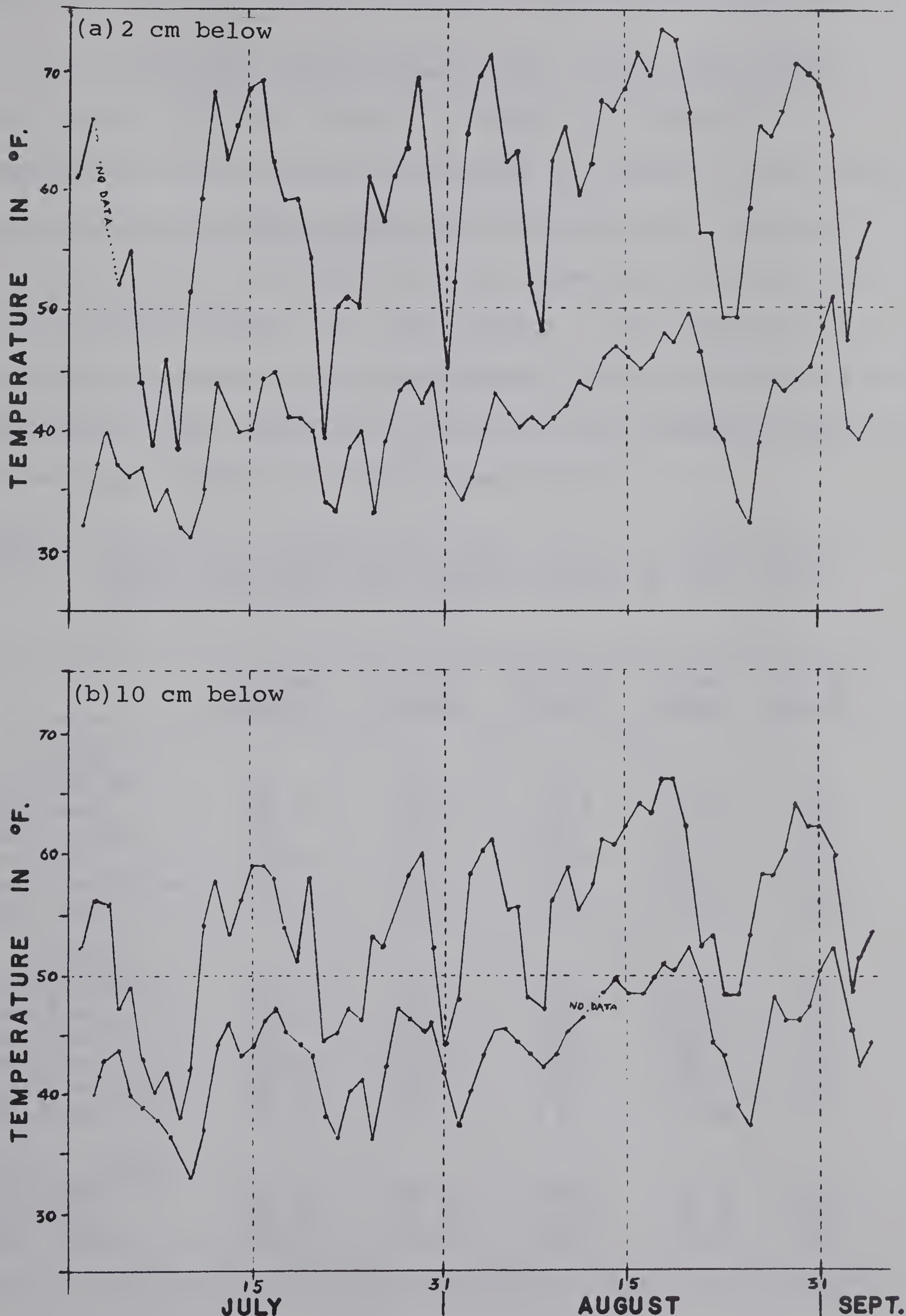


FIGURE 8. MAXIMUM AND MINIMUM TEMPERATURES AT TWO LEVELS BELOW THE GROUND SURFACE AT THE SIGNAL MOUNTAIN METEOROLOGICAL STATION IN 1967.



grow this tall, but most of those in exposed habitats do not.

At 2 cm below ground temperatures varied from 32° to 73°, a range of 41°F. (Fig. 8a, Table 4). Maximum temperatures at this level fluctuated as greatly as did those above ground, but there was a decided moderating influence of the ground on the minima and the temperature did not drop below freezing during the study period. This moderation may be of some importance to alpine plants, whose root/shoot ratios are usually high (Daubenmire 1941), as most metabolic processes proceed more rapidly at higher temperatures.

TABLE 4. SUMMARY OF TEMPERATURE DATA IN °F. AT FIVE LEVELS ABOVE AND BELOW THE GROUND SURFACE AT THE SIGNAL MOUNTAIN STATION IN 1967.

	135 cm ABOVE	50 cm ABOVE	18 cm ABOVE	2 cm BELOW	10 cm BELOW
JULY					
Absolute Max.	66	71	71	69	60
Mean Max.	53.5	56.1	55.5	56.0	51.0
Absolute Min.	28	26	26	31	33
Mean Min.	41.6	40.0	40.0	39.0	41.5
Absolute Range	38	45	45	38	27
Mean Temp.	47.6	48.2	47.8	47.5	46.3
AUGUST					
Absolute Max.	71	73	73	73	66
Mean Max.	60.0	62.5	62.5	63.0	57.5
Absolute Min.	33	30	30	32	37
Mean Min.	46.0	44.4	44.5	42.5	45.3
Absolute Range	38	43	43	41	29
Mean Temp.	53.0	53.5	53.5	52.8	51.4
JULY + AUGUST					
Mean Max.	56.8	59.3	59.0	59.5	54.3
Mean Min.	43.8	42.2	42.2	40.8	43.4
Mean Temp.	50.3	50.7	50.7	50.2	48.9

At 10 cm below ground there was moderation of both maximum and minimum temperatures (Fig. 8b) with the range of 33°F. (33°-66°) being the smallest of all the levels measured.

2. Microenvironmental Stations

Air Temperatures

Maximum and minimum air temperatures at the eight microenvironmental stations are compared with those of the major Signal station (M) in Tables 5 and 6 (actual temperatures in Appendices IV and V). All the temperatures concerned were measured at 18 cm above the ground.

The major station records showed the smallest diurnal range, with low mean maximum and nearly the highest mean minimum temperatures. This may have been partly due to (1) the site chosen for the station, (2) the location of the sensor in the meteorological shelter within which a temperature lag was caused by large metal instruments, and (3) less effective radiation shielding around the Taylor thermometers (see Plate 4) which may allow bulb temperatures to exceed ambient air maxima and fall below ambient air minima.

Variation among sites was much greater in maximum than in minimum temperatures. South slope sites had somewhat higher average minima and much higher maxima than did the N slope sites.

TABLES 5 & 6.

LEGEND

Microenvironmental Stations:

M = Major station, used for reference

1 = Lookout, slightly to N of ridge

2 = Scree area on S slope

3 = Grassy S slope

4 = Summit

5 = Northwest Draw

6 - Xeric site on N slope

7 = Mesic site on N slope

8 = Very wet site on N slope

(Locations shown in Fig. 3, p.10)

\+ temperature higher than reference (M)

\- temperature lower than reference

= temperature equal to reference

Actual values are in Appendices IV and V.

TABLE 5. MAXIMUM AIR TEMPERATURES IN °F. AT MICROENVIRONMENTAL STATIONS COMPARED TO THOSE OF MAJOR STATION ON SIGNAL MOUNTAIN.

DATE	M	1	2	3	4	5	6	7	8
July 2-4	66	+8	+11	+7	+1	+6	+6	n.d.	-7
4-6	52	+1	+10	+9	+6	+6	+3	n.d.	-4
6-9	44	-1	+7	+4	+2	+7	+4	n.d.	+8
9-10	51	+6	+6	+5	+4	+5	+5	n.d.	+4
10-12	65	+4	+8	+8	+7	+4	+8	+9	-3
12-14	71	+2	+7	+4	+2	+1	+2	+3	-9
14-16	68	+4	+6	+4	+3	+2	+3	+6	-6
16-17	69	+4	+6	+3	+3	+6	+5	=	-7
17-19	64	+4	+7	+3	+1	+5	+2	+4	-4
19-25	55	+1	+7	+3	+1	+4	+5	+6	+1
25-28	64	+5	+8	+4	+6	+3	+3	+6	-2
28-31	63	+6	+10	+7	+7	+5	+7	+7	-3
AVERAGE OF JULY READINGS	61.1	+3.8	+8.0	+5.1	+3.6	+4.5	+4.4	+5.1*	-2.7
Aug. 1-4	66	+5	+8	+4	+4	+5	+5	+3	-3
4-8	63	=	+11	+9	+9	+2	=	+4	-1
8-11	69	=	+5	+2	+1	+1	+1	=	-6
11-14	68	+2	+5	+4	+2	+2	+1	+4	-4
14-18	72	+1	+8	+5	+4	+3	=	+6	-4
18-21	75	+3	+6	+3	-1	+3	+3	+2	-4
21-25	54	+3	+7	+6	+4	+6	+1	+4	-1
25-28	68	=	+6	+5	+2	+2	=	+2	-5
28-31	71	+2	+6	+7	+4	+2	+1	+1	-3
AVERAGE OF AUGUST READINGS	67.3	+1.6	+6.9	+5.0	+3.2	+2.9	+1.3	+2.9	-3.4
Sept. 1-4	73	=	+4	+5	-	=	-2	-1	-16

* Based on eight readings and therefore is not a true comparison with the other sites which had four earlier readings.

n.d. = no data

TABLE 6. MINIMUM AIR TEMPERATURES IN °F. AT MICROENVIRONMENTAL STATIONS COMPARED TO THOSE OF MAJOR STATION ON SIGNAL MOUNTAIN.

DATE	M	1	2	3	4	5	6	7	8
July 2-4	37	=	=	+1	+2	-4	+2	n.d.	+1
4-6	35	+2	=	=	-2	=	=	n.d.	+1
6-9	26	+3	+2	+2	=	+2	+2	n.d.	+4
9-10	31	-2	-1	-2	=	-1	=	n.d.	=
10-12	41	=	-3	-2	-2	-2	-3	-6	-9
12-14	42	+1	-2	=	-2	-6	-5	-5	-6
14-16	42	=	-4	-2	-3	-9	-5	-6	-7
16-17	48	+3	+1	=	+1	-10	-4	-3	-6
17-19	38	+1	=	-1	-1	-4	-4	-6	-5
19-25	29	+1	=	+3	+1	=	+2	+3	+4
25-28	44	-1	-2	-1	=	-6	-4	-8	-5
28-31	33	-1	=	+1	-1	-1	=	=	+2
AVERAGE OF JULY READINGS	37.1	+0.4	-0.8	-0.1	-0.6	-3.4	-1.6	-3.9*	-2.3
Aug. 1-4	35	-2	-1	-2	=	-3	-2	-4	-3
4-8	39	-1	-2	-2	-2	-6	-4	-5	-5
8-11	44	+6	+1	=	=	=	+1	-1	-2
11-14	48	-1	=	-1	+1	-1	-1	-3	-3
14-18	49	=	-3	-3	=	-7	-7	-8	-4
18-21	43	=	=	+1	-1	-3	=	=	-3
21-25	30	-2	-2	-3	=	-7	-5	-7	-5
25-28	40	+1	+2	+1	+2	-1	-1	-5	-5
28-31	46	-2	-1	=	+1	-7	-4	-6	-10
AVERAGE OF AUGUST READINGS	41.6	-0.1	-0.7	-1.0	+0.1	-3.9	-2.6	-4.3	-4.4
Sept. 1-4	36	+1	+2	-1	n.d.	+1	+3	+3	+2

* Based on eight readings and therefore is not a true comparison with the other sites which had four earlier readings.

n.d. = no data.

PLATE 5. Microenvironmental station ME-5 located near the top of the Northwest Draw. The styrofoam-shielded maximum-minimum thermometer was less than 2 m from the snow edge on the day of installation (July 1, 1967), as shown below.

The depression of local temperature by cold water is seen in the data from ME-8, where the thermometer was surrounded by snowmelt water from the seepage spring (see Plate 22, p. 158). This site consistently had lower maximum and minimum temperatures. The *Salix arctica - Arctagrostis* community found here included several species not found at other sites, probably a reflection of both abundant moisture and lower temperature.

The second lowest minimum temperatures were recorded at ME-5 in the Northwest Draw (Plate 5). This site is a rather shallow topographic basin in which cold air probably collects. During the earlier part of July, while it still contained snow, minimum temperatures were lower than at the very wet site (ME-8).

The scree site (ME-2) was usually the warmest during the day, with the rock fragments absorbing energy and transferring heat from insolation. Minimum temperatures were third highest when compared with other sites. These generally higher temperatures may have promoted earlier anthesis in species growing on the scree than was found on other sites. The warming effect of rock fragments was particularly evident in cushion plants, for example *Silene acaulis* (Plate 6), *Crepis nana* and *Potentilla nivea*. Flowering was initiated at the periphery of the cushion, closest to the rock fragments, two or three days earlier than in the centre. This centripetal pattern of flowering

PLATE 6. *Silene acaulis* cushion growing on scree, illustrating the warming effect of the rock fragments on the initiation of anthesis at the periphery of the cushion. The buds on the central portion of the cushion opened two to three days later.

The small rock fragments on the top of the cushion were probably moved there by wind and/or forces of gravity and diurnal needle-ice combined.

(Photographed June 24, 1967).

dates did not occur on sites with a more continuous vegetation cover; in this case flowering dates were random over the cushion.

Temperatures at the summit station (ME-4, Plate 7) were similar to those at the lookout site (ME-1). Maxima were intermediate to those of other sites, but minima, similar to those at the major station, were the highest. Maximum temperatures at ME-4 were somewhat lower during early July, possibly due to the presence of snow immediately below and on the north side of the summit.

Soil Temperatures

Spot readings of soil temperatures at 10 cm depth were obtained at the microenvironmental stations at varying times of day. In order to relate these temperatures to each other thermograph records made at the same time at the major station were used as reference temperatures (Table 7, complete data in Appendix VI). Soil temperatures were not recorded at the lookout site (ME-1).

Soil temperatures showed a negative correlation with the soil moisture regime of each site: higher temperatures prevailed at the drier sites, with the wettest site consistently registering the lowest soil temperatures, due, in part, to the higher evapotranspiration rate and latent heat loss.

PLATE 7. Microenvironmental station ME-4 at the summit of Signal Mountain. The many boulders in this fellfield contribute to a somewhat more stable microenvironment at the ground level as they tend to absorb solar energy and deflect some of the wind.

Jasper is in the valley in the middle distance and Yellowhead Pass is beyond in the far distance.

(Photographed July 16, 1967).

TABLE 7. SOIL TEMPERATURES IN °F. AT MICROENVIRONMENTAL STATIONS COMPARED WITH THE CORRESPONDING TEMPERATURES AT THE MAJOR STATION ON SIGNAL MOUNTAIN.

		ME-2		ME-3		ME-4		ME-5		ME-6		ME-7	ME-8	
DATE	M	O*	V**	O	V	O	V	O	V	O	V	V	W***	V
July 4	45-47	+9	+3	+4	-1	+5	-3	-9	-9	+3	-4	·	-5	-5
9	36-38	+2	+1	+1	+1	=	-1	·	-5	+1	+1	·	-2	-2
10	44-46	+2	-2	=	-4	-1	-3	-6	-10	=	-6	·	-2	-5
12	48-58	+1	-3	-3	-9	-4	-6	-8	-8	-6	-11	-13	-13	-12
14	50-56	+2	-3	=	-7	=	-5	-7	-9	-4	-9	-9	-13	-13
16	56-58	+1	-3	=	-6	-4	-6	-12	-14	-4	-1	-11	-16	-16
17	50-54	+2	=	-1	-3	-2	-3	-8	-7	-2	-8	-8	-14	-14
19	46-49	+1	+1	=	-2	-1	-1	-5	-5	-2	-2	-4	-10	-10
25	44-51	-3	-5	-3	-5	-3	-6	-4	-7	-3	-8	-8	-7	-7
28	50-55	-1	-4	-4	-6	-4	-6	-7	-11	-2	-4	-5	-13	-13
31	42-44	+2	=	=	-1	-1	-3	-1	=	=	=	=	-7	-7
MEAN		+1.6	-1.2	+0.5	-4.0	-1.2	-4.0	-6.1	-7.7	-1.7	-4.7	-5.4	-9.3	-9.5
Aug. 4	50-61	=	-3	-3	-3	-4	-6	-5	-6	-6	-13	-11	-13	-16
8	45-46	+1	+1	+1	+1	-1	-1	-1	-2	-2	-2	-2	-9	-9
11	49-53	+2	=	=	-3	-1	-1	-3	-3	-3	-6	-6	-11	-11
14	51-46	+3	-1	-1	=	-2	-2	-9	-5	-2	-2	-4	-10	-12
18	57-62	=	-3	-3	-6	-4	-4	-8	-10	-7	-9	-14	-12	-18
21	49-52	+3	+3	+3	+2	=	+2	+1	-1	-2	-2	-5	-10	-12
25	39-53	-1	-3	-3	-4	-4	-6	-9	-12	-1	+1	=	-3	-6
28	50-56	+1	-3	-3	-3	-2	-4	-8	-10	-5	-5	-8	-10	-12
31	51-62	+2	+1	+1	=	-1	+1	-2	-4	-5	-12	-10	-12	-14
MEAN		+1.2	-0.7	0	-1.8	-2.1	-2.3	-5.0	-6.0	-3.7	-5.6	-6.7	-10.0	-12.2
Sept. 4	45-52	+2	+2	+1	-2	-2	-2	-1	-1	-1	-3	-4	-9	-9
MEAN FOR SEASON		+1.5	-1.0	+0.3	-2.9	-1.7	-3.1	-5.6	-6.6	-2.5	-5.0	-5.8	-9.6	-10.6

* open area, devoid of vegetation ** vegetated area ***water

At all locations with open, unvegetated ground, soil temperatures under vegetation were consistently lower than those under bare ground. This probably was chiefly due to (a) the insulation of the ground by the plant cover with consequent reduced heat absorption by the soil, and (b) the cooling of the ground by evapotranspirational loss of moisture.

The scree station (ME-2) consistently showed the highest soil temperatures, under both bare ground and vegetation mats, as well as the highest air temperatures. This site receives intense insolation because of its southern aspect. In addition to the heating of the rock fragments by solar radiation, the coarse texture of the scree soil promotes dry conditions near the surface during much of the summer.

The other S slope station (ME-3) was somewhat lower in elevation and had better developed soil not quite so coarse in texture as at ME-2; it had the second highest soil and air temperatures.

The third warmest soil was present at the summit site (ME-4), which had only a slight northern aspect, much exposed rock and very shallow soil (Plate 7). It often took many tries before the thermometer probe would reach the desired depth of 10 cm. The poorly developed and small amount of soil, together with the great amount of wind this site is subjected to, promote rapid evapotranspiration of

soil moisture.

Soil temperatures at N slope stations were all lower than those at S slope sites. The very wet site (ME-8), which was immediately below a seepage spring, had much lower soil temperatures than the other stations. Temperatures here were not obtained from mineral soil but from moss, chiefly *Sphagnum warnstorfianum*, which has accumulated to a considerable depth and forms the substrate for rooting of higher plants. Since the moss was saturated the temperature was usually the same as, or similar to, that of the open water which was shallow and moving slowly.

The Northwest Draw (ME-5) had the second lowest mean soil and air temperatures. Temperatures were particularly low during the earlier part of July due to late-lying snow in the depression (Plate 5). Snow from two summer storms also remained longest at this site.

The mesic N slope station (ME-7) had the third lowest mean soil temperature although the mean air temperatures did not rate this position. This is a fairly moist site since it receives meltwater during most of the summer from late-lying snowpatches on the slope some distance above.

The xeric station on the N slope (ME-6) had the highest soil temperatures of all the N slope sites.

B. Solar Radiation

Cloudy conditions accompanying unstable weather were generally less prevalent during the summer of 1967, particularly in August, than in the summers of 1968 and 1969. It is therefore likely that insolation was proportionally higher in 1967 than during the two succeeding summers, and probably higher also than the long-term average.

TABLE 8. SOLAR RADIATION AT THE MAJOR STATION ON SIGNAL MOUNTAIN IN 1967.

PERIOD	MEAN HOURS OF DAYLIGHT	TOTAL RADIATION	MEAN LY/DAY	DAILY MAX.	DAILY MIN.	MEAN LY/DAY HR.
June 23-30*	16:55	4,140	591	810	198	35
July 1-31	16:19	16,056	581	837	198	30
Aug. 1-31	14:41	15,219	481	675	198	34
Sept. 1-4	13:33	1,251	313	432	180	23
Summer	15:07	36,666	502	837	180	33

* excluding June 27 (no data)

Daily solar radiation data were recorded in langleys, i.e., g-cal/cm^2 (Table 8, complete tabular data in Appendix II).

The weather was variable in July, but during August skies were usually much clearer, resulting in far more sunny days. Thus, although the mean solar radiation per day was 90 ly higher in July than in August (581 ly vs. 491), mean radiation per daylight hour was lower (30 vs. 34 ly). The effect of change in solar angle is also shown in the

monthly maxima, 837 ly in July and 675 ly in August.

Records of solar radiation at the valley station of Devona were incomplete and varied from day to day when compared with those of Signal Mountain (Appendix VII). Mean radiation values were slightly higher on Signal, 552 ly on Signal compared with 540 ly at Devona during August, but this difference is not considered significant.

C. Wind

The air was almost constantly in motion on Signal Mountain. Periods of calm were relatively rare and of short duration, at least during daylight hours.

Winds came from every direction except E, ESE and SE; the lack of easterly winds was chiefly due to obstruction by the higher mountains of the Maligne Range. Winds from the NE were not common, but when they did occur they were usually associated with precipitation, particularly snow. Prevailing winds came from the WSW, down the Miette River valley from Yellowhead Pass. Daytime winds from the S and SW were also common, and generally of high velocity, probably due to the reinforcing effect of upslope winds on horizontal winds. Downslope winds were no doubt present at night, but field observations were not made during that portion of the day.

1. Constant Wind Records at the Lookout Station

Records for the totalizing anemometer during four

parts of the day are summarized in Table 9 (complete data in Appendix VIII). During the 75-day study period in 1967 (June 23 to September 5) the anemometer recorded 17,987 km (11,177 miles) of wind, an average of 10.0 km/hr (6.2 mph).

A correlation of wind with temperature was noted (Table 9, Figure 7), with the warmer weather of August and early September associated with higher wind velocities. The highest daily mean velocity, 17.4 km/hr, was recorded on August 26 and the second highest, 16.3 km/hr, on September 1, 1967. It was suspected, however, that the anemometer may not have been accurate at higher wind speeds and values might actually have been higher.

TABLE 9. MEAN WIND VELOCITY IN KM/HR AT THE SIGNAL MOUNTAIN LOOKOUT STATION DURING FOUR TIME PERIODS.

	TIME PERIODS (M.S.T.)			
DATES	8 p.m. – 8 a.m.	8 a.m. – 12 noon	12 noon – 4 p.m.	4 p.m. – 8 p.m.
July 1-31	9.3	8.0	9.5	9.3
August 1-31	9.5	8.4	10.5	11.4
September 1-4	13.2	10.2	13.2	15.8
July 1 - Sept. 4	9.9	8.7	10.3	10.9

The morning period (8 a.m. to noon) had the lowest wind speeds, while afternoon and early evening, the warmest period of the day, had the strongest winds (Table 9). Well after the beginning of the season it became evident that wind velocity increased noticeably about 11 a.m. Had the time periods been divided differently, the diurnal pattern

of winds would probably have been more pronounced.

2. Spot Wind Measurements at Microenvironmental Stations

Spot readings of wind velocity were made when air and soil temperatures were recorded at the microenvironmental stations. Although there was generally a spread of at least two hours between the first and last readings, and the order of station visitation varied occasionally, the measurements were usually made during the period between late morning and late afternoon when wind velocities tended to be highest. It is thought, therefore, that comparisons between stations (Table 10) would probably have some validity. There were eight readings in July, nine in August, and one in September. Average and gust wind velocities, together with the times and the reference mean speed registered on the totalizing anemometer for the period, are given in Appendix IX. No readings were made at the lookout station (ME-1).

The scree station (ME-2) had the highest wind speeds, including both average and gust readings. The highest gust recorded here was 72 km/hr on July 25, with a S wind. However, much higher wind velocities did occur several times, particularly in August and early September, but were not measured. It was considered unwise to venture onto the scree slope, with its airborne rock fragments, when wind velocity was maximal.

The summit station (ME-4) was nearly as windy as ME-2. Although the mean recorded wind velocity here was close to that at the scree station, gusts usually were not as high. Peak gusts (53 km/hr) were recorded on July 17 and August 4, with winds from the S both times.

TABLE 10. SPOT READINGS OF WIND VELOCITY IN KM/HR AT MICROENVIRONMENTAL STATIONS ON SIGNAL MOUNTAIN

	STATIONS						
	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
July 12-31							
MEAN AVERAGE*	25.4	21.1	24.3	9.0	11.9	10.6	8.2
MEAN GUST	35.6	31.4	33.8	15.6	22.0	17.9	21.9
PEAK GUST**	72	34	53	26	40	29	39
August 4-31							
MEAN AVERAGE	16.6	10.8	15.6	3.7	6.8	5.5	5.1
MEAN GUST	23.7	17.1	20.9	8.7	12.3	10.8	11.2
PEAK GUST**	56	35	55	19	23	29	39
Sept. 4							
MEAN AVERAGE	24	16	24	3	16	14	16
PEAK GUST**	35	26	47	8	23	21	26
1967 Season							
MEAN AVERAGE	20.9	15.6	20.0	5.5	9.7	8.4	7.1
MEAN GUST	29.6	23.9	28.1	11.7	17.2	14.5	16.8
PEAK GUST**	72	35	55	26	40	29	39

** NOTE: Peak gust recorded, not the highest gust that occurred.

* Average refers to the readings of prevailing wind velocity.

The other S slope station (ME-3) was the third windiest. This station was only slightly lower in elevation than ME-2 but its more easterly location on Signal Mountain resulted in some topographic protection, from the W in particular, which ME-2 did not have.

All four N slope stations registered considerably lower wind velocities than the two on the S slope. The westernmost of these (ME-6) had the highest spot readings; the peak gust (40km/hr) was recorded on July 17 with a W wind.

Although ME-5 was the highest in elevation on the N slope, it gave the lowest wind velocity readings and was rated the most protected station. The other two N slope stations (ME-7 and 8) gave intermediate readings compared with ME-5 and 6. The wet site station (ME-8) was in a slightly more depressed location and gave lower average readings than the terrace riser site (ME-7).

It should be stressed that the wind data from the microenvironmental stations were not absolute: the "averages" compared were relative and not the actual mean velocities nor the highest gusts which occurred at each station. Further, the data from spot readings may lead one to believe that wind velocity was generally higher in July than in August, but the reverse was actually true as shown by the totalizing anemometer data. As mentioned earlier, readings during August and early September were made on calmer days when it was considered easier, and safer, to cover the microenvironmental station circuit. It is thought, however, that the biased "averages" still form a valid basis for assessing the relative windiness of stations.

D. Precipitation

A total of 57 mm (2.33 in.) of precipitation was recorded at the Signal Mountain lookout site during the 1967 study period. Of this, 44 mm came in July, 9 mm in August, and 4 mm in the first four days in September (Fig. 7, Appendix II). Most of the rain came at night during all three months. This nocturnal pattern was not evident in 1968 and 1969.

Snow can and usually does fall on the alpine zone of Signal Mountain during every month of the year. However, much less snow fell in 1967 than is probably received during an average summer; a total of about 10 cm was recorded during the study period. In contrast, on August 5, 1969, over 25 cm of snow fell and was dry enough to be blown into drifts over 1 m deep.

According to Jasper meteorological records, the 1967 growing season was preceded by an unusually large winter snowfall of 170.7 cm compared to the annual normal of 125 cm. The resultant large accumulation of snow on Signal Mountain probably had at least two major effects on alpine vegetation: (1) later dates of vernation and anthesis due to later snow release, and (2) more favourable soil moisture regimes for sites with melting snowpatches upslope. The latter effect, however, may have been at least partly counteracted by lower than normal precipitation in August.

The spring of 1969 was preceded by a lower than average snowfall (105.4 cm at Jasper) and peak anthesis in most of the dominant species occurred three weeks earlier than during the spring of 1967. This early flowering, however, was probably related at least as much, if not more, to the prevalence of higher temperatures in May and June, 1969.

E. Synthesis of Meteorological Data

1. Major Station

In order to show the 1967 summer trends, daily values of the meteorological factors measured on Signal Mountain have been plotted together (Fig. 7, numerical data in Appendix II), beginning on July 1 when all data became available, and ending on September 4 after which date the station was dismantled.

Daylight, viz., the period between sunrise and sunset, decreased from 16 hrs. 55 min. on July 1 to 13 hrs. 27 min. on September 4, a difference of 3 hrs. 28 min. in the 66 - day interval. This decreased day length was reflected in the daily solar radiation totals which were generally lower in August although skies were clearer then than in July.

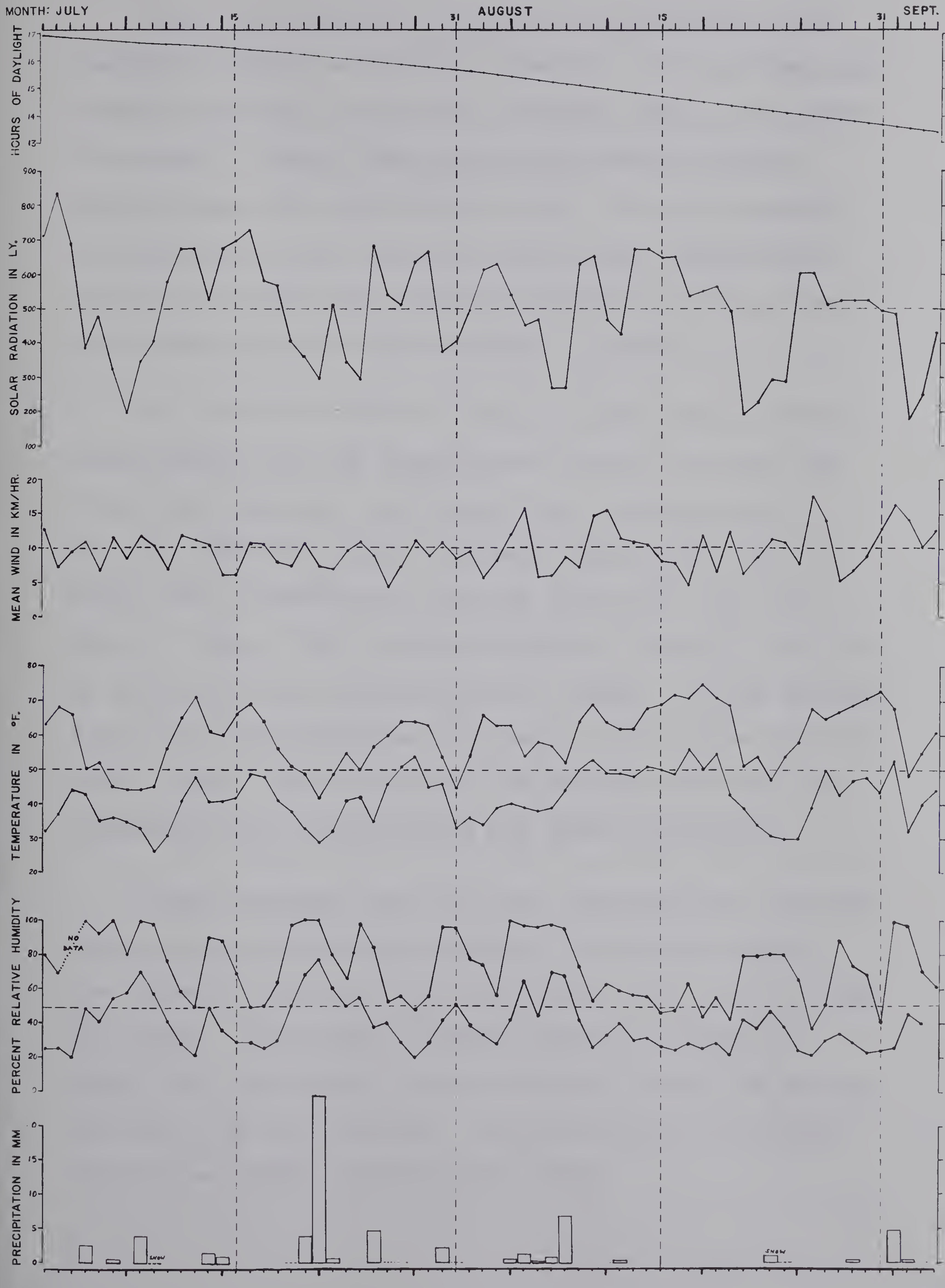
Some cloud was present nearly every day of the study period, particularly during the afternoon. Since very low radiation values resulted from heavy cloud cover, they were usually but not invariably associated with some form of precipitation.

FIGURE 9. DAILY METEOROLOGICAL DATA FOR THE 1967 STUDY PERIOD ON SIGNAL MOUNTAIN.

1. Total hours of daylight (data from the Canada Department of Transport)
2. Total solar radiation received on a horizontal surface
3. Mean wind velocity
4. Maximum and minimum air temperatures at 135 cm showing diurnal range
5. Maximum and minimum relative humidity at 18 cm, showing diurnal range
6. Total precipitation (dotted line indicates trace amount)

(Complete data in Appendix II)

FIGURE 9. DAILY METEOROLOGICAL DATA FOR THE 1967 STUDY PERIOD ON SIGNAL MOUNTAIN.



There is a similarity between the temperature and radiation curves, as would be expected, but the former are somewhat smoother, especially in August when it was warmer in general. August temperature data showed a greater diurnal range than did those of July. This was probably related more to the change in solar angle, resulting in shorter day length and reduced insolation per day, than to the warmer and more stable weather in August.

The relative humidity curves show the usual converse relationship with the temperature curves, but again the latter are smoother, particularly the minimum curve. Relative humidity values were more consistently low in August when temperatures and wind velocities were both higher. These three factors undoubtedly caused a high rate of potential evapotranspiration in August. A high moisture stress must have developed in the thin and coarse-textured alpine soils, since snowbanks and meltwater had all but disappeared and precipitation was almost negligible.

Vapour pressure deficits were calculated for the mean temperatures and relative humidity for July and August. The value for July was 5 mb (3.8 mm Hg) and 10 mb (7.5 mm) for August. The highest deficit probably occurred on August 18, the warmest day of the season, when the maximum VPD was 22 mb (16.5 mm Hg). A wind velocity of 12 km/hr would have further increased the value.

There was some correlation between wind and precipitation; wind velocity was generally greater than the seasonal average during rain and/or snow storms. These storm winds were probably caused mainly by pressure differences. The highest wind velocities occurred during the warm, dry weather of August when slope winds added their energy to the horizontal air movements. Mean daily velocity varied from a low of 4.3 km/hr (2.7 mph) on July 26 to a high of 17.4 km/hr (10.8 mph) on August 26.

2. Microenvironmental Stations

When the microenvironmental data are compared in graphical form (Figs. 10, 11, 12; data from Tables 4, 5, 6, 10) there is a general trend for the factors measured to have low values at the N slope stations and high values at the S slope stations. Thus, the S slope sites are shown to be the warmest and the windiest. The summit station (ME-4) is between the two groups in air and soil temperature rank, but close to the windiest site (ME-2) in wind velocity rank.

Arranged in an ecological series from cool and calm to warm and windy, the microenvironmental stations appear thus: ME-8, 5, 7, 6, 4, 3, 2. It can therefore be concluded that slope aspect and other topographic features are important determinants of the microclimates of the seven microenvironmental stations. The comparatively small elevational differences concerned, ranging from 2205 m

at ME-6 to 2311 m at ME-4, did not appear to be directly correlated with the values of the measured factors.

FIGURE 10. RELATIONSHIP BETWEEN MICROENVIRONMENTAL STATIONS ON SIGNAL MOUNTAIN BASED ON SPOT READINGS OF WIND VELOCITY AND SOIL TEMPERATURE.

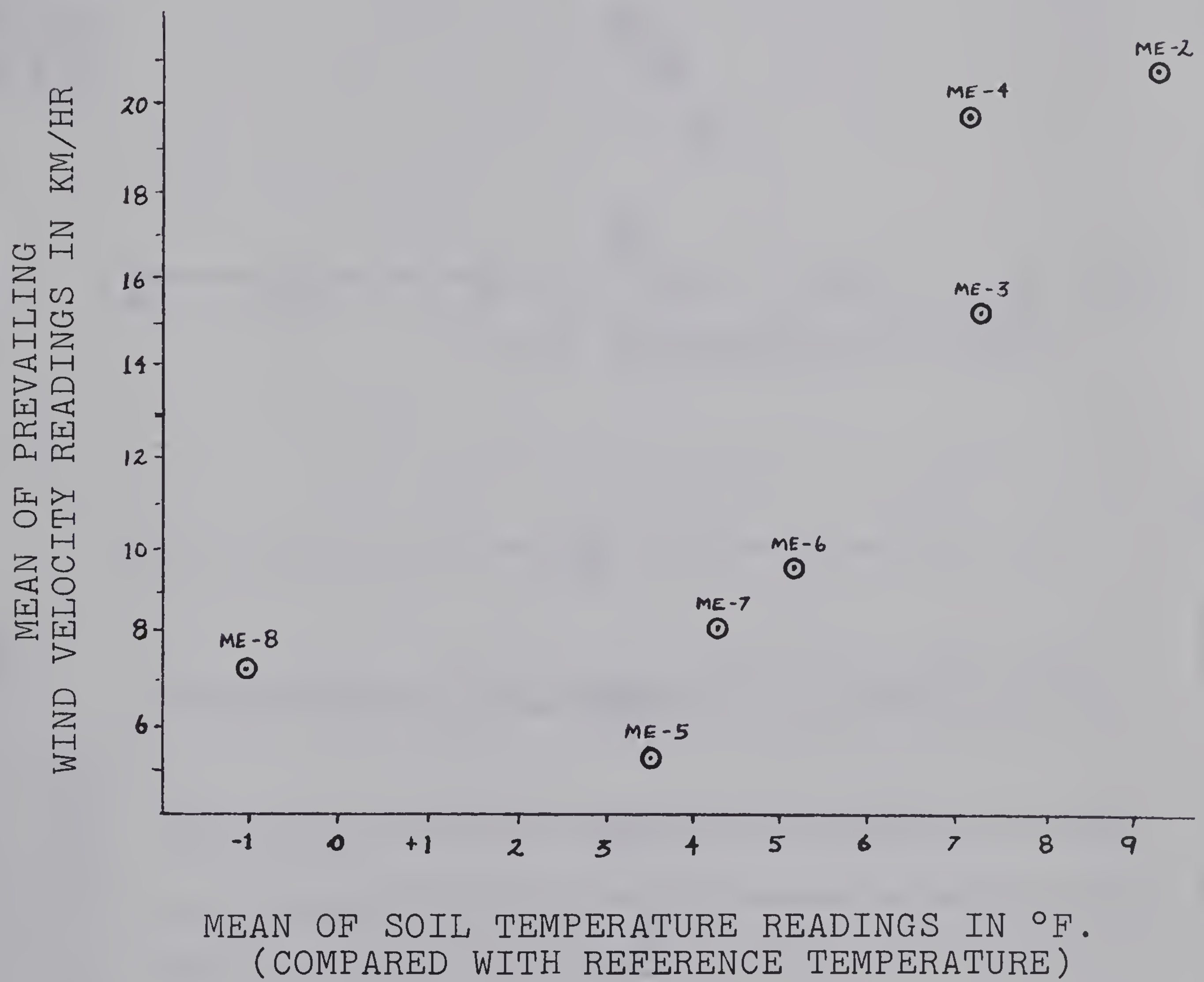


FIGURE 11. RELATIONSHIP BETWEEN SIGNAL MICROENVIRONMENTAL STATIONS BASED ON AIR AND SOIL TEMPERATURE READINGS.

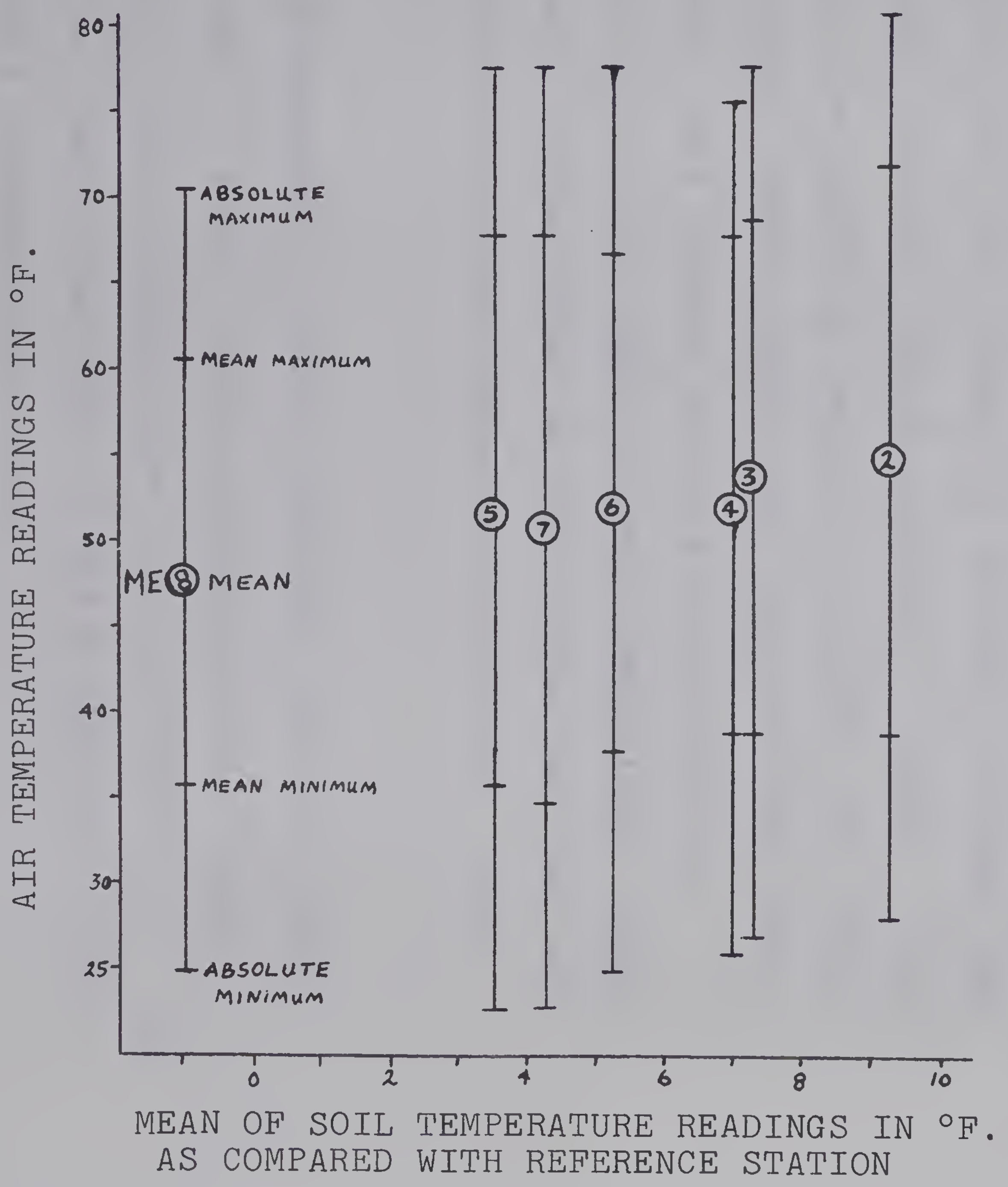
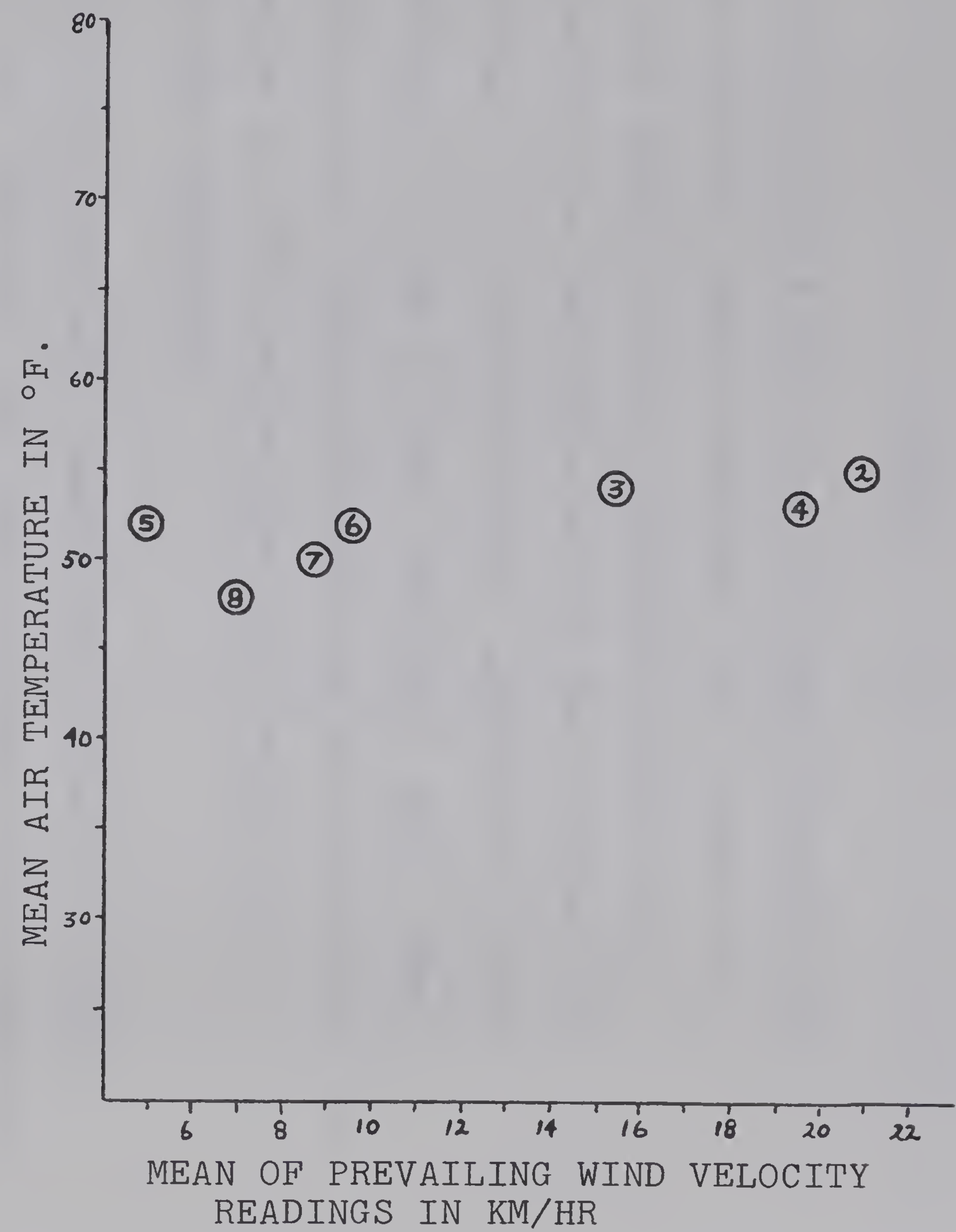


FIGURE 12. RELATIONSHIP BETWEEN SIGNAL MICROENVIRONMENTAL STATIONS BASED ON AIR TEMPERATURE AND WIND VELOCITY READINGS.



SOILS

The soils of the alpine zone on Signal Mountain are mostly very shallow, poorly developed, and coarse in texture. They appear to have developed chiefly from weathered bedrock on the ridges and on the S slope, but parent materials also include varying amounts of glacial drift, especially on the N slope (Westgate, pers. comm.). To a limited extent, aeolian deposits may also be present on the N slope as this is the lee side with respect to prevailing wind conditions.

Most of the soils have considerable amounts of gravel and cobbles, at least in the lower portions of the profiles. All but the scree soils showed an increase in gravel and cobble-sized particles with an increase in depth. Soils of the S slope are generally coarser in texture than those of the N slope; gravel content was found to range from 25% to almost 100% (scree) on the S slope and from practically nil to 67% under N slope communities. Sand content was a little higher on the S slope but clay and silt fractions were much higher on the N slope (Table 11).

The percentage of coarse fractions (gravel + sand) exceeded that of fines in all horizons of the S slope and ridge-top soils (communities A to G in Table 11). The opposite was true of the upper (A and B) horizons of the N slope soils (communities H to N).

TABLE 11. ANALYSES OF ALPINE SOILS FROM SIGNAL MOUNTAIN.

COMM-UNITY	DOMINANT COVER	STAND NO.	ASPECT and SLOPE	DEPTH (cm)	ROOT ZONE (cm)	% GRAVEL	% SAND	% SILT	% CLAY	<2 mm FRACTION TEXTURE	pH	CONDUCT. (mmohs)	ppm AVAIL. N	ppm AVAIL. P	ppm AVAIL. K	% WATER (O.D. BASIS) F.C.	P.W.P.	AVAIL.	DATE COLL.
A	SCREE	7S	SSW 12°	0-5		73	21	4	2	LS	6.0	0.07	0	6	88	9	5	4	July 27/67
				5-23	5	52	28	15	5	SL	5.6	0.07	0	5	81	18	7	11	
				23-34	23	70	17	10	3	SL	5.4	0.07	0	4	59	17	6	11	
		4S	S 14°	0-3						S			0						July 18
				3-8		45	34	15	6	SL	6.1	0.07	0	3	49	16	5	11	
				8-28	8	72	20	6	2	SL	5.5	0.10	0	3	37	17	8	9	
				28-40	28	45	27	24	4	SL	5.7	0.10	0	3	35	17	6	11	
	Dryas	7D	SSW 12°	0-10	0	66	39	11	4	SL	5.9	0.30	1	8	129	31	22	9	July 27
				10-23	23	60	22	13	5	SL	5.7	0.20	0	5	82	18	9	9	
				23-40		78	14	6	2	SL	5.9	0.07	0	4	77	14	7	7	
		4D	S 14°	0-5	0	25	56	14	5	SL	6.2	0.10	0	5	84	16	9	7	July 18
				5-25	25	56	24	16	4	SL	5.9	0.07	0	3	39	18	7	11	
B	Dryas-GRAMIN.	13	S 15°	1-4	0	40	26	17	17	CL	6.3	0.20	1	5	123	66	44	22	Aug. 19
				4-25	20	51	22	21	6	L	5.9	0.10	0	1	47	23	7	16	
C	Dryas-Kobresia	1	WSW 20°	0-6	0	41	39	12	12	SL	6.3	0.50	21	5	65	47	42	5	July 10
				6-20	30	60	30	6	4	SL	6.3	0.50	4	3	35	22	11	11	
D	Dryas-LICHEN	6		0-3	0														July 26
				3-8		27	37	20	16	L	4.8	0.20	0	6	63	32	19	13	
				8-25	17	31	36	25	8	SL	5.4	0.10	0	1	33	20	7	13	
E	Dryas-MOSS	2	N 7°	0-8	0	22	35	30	13	L	5.4	0.50	21	8	92	51	29	22	July 11
				8-40	30	30	34	32	4	SL	5.7	0.20	3	3	30	23	6	17	
				40+		47	28	22	3	SL	5.6	0.10	0	4	30	24	6	18	
F	Cassiope tetr.-Dryas	3	NW 13°	0-7	0	10	48	33	9	SL	5.0	0.30	3	8	65	50	36	14	July 17
				7-20	20	15	40	38	7	L	5.1	0.20	0	6	20	44	17	27	
				20-28		50	22	22	6	L	5.2	0.10	0	1	20	24	6	18	
G	Dryas	11D	NE 6°	0-5	0	5	29	30	36	CL	5.3	0.10	0	6	119	117	85	32	Aug. 16
				5-30	28	33	15	15	37	C	4.9	0.10	0	3	90	45	26	19	
	Empetrum	11E	N-NE	0-5	0	44	18	13	25	C	5.2	0.10	0	5	127	46	27	19	Aug. 15
				5-40	28	62	15	6	17	C	5.1	0.10	0	3	94	37	21	16	
	GRAVEL	11G	NE	1-28	2 -20	28	32	33	7	L	5.4	0.10	0	4	55	23	6	17	Aug. 15
J	Cass.m.-Phyll.	5B	N 15°	0-12	0	6	27	52	15	L	5.2	0.40	4	6	168	80	56	24	July 19
				12-40	30	67	16	14	3	SL	5.6	0.10	0	1	49	18	6	12	
		8B	NNE 13°	0-4	0	0+	26	51	23	L	5.5	0.50	0	10	319	149	116	33	July 29
				4-20		3	23	54	20	SiL	5.6	0.10	0	4	118	73	20	53	
				20-40	33	56	22	17	5	SL	5.5	0.10	0	1	22	20	7	13	
?H	Dryas	8T	ENE 21°	0-5	0	0+	27	35	38	CL	5.5	0.30	3	8	107	156	106	50	Aug. 9
				5-12		13	19	38	30	CL	5.2	0.30	1	4	61	70	34	36	
				12-50	33	57	24	15	4	SL	5.5	0.10	0	3	37	18	5	13	
K	Slx.a.-Arctagr.	12	NNW 4°	0-7	0	0				O									Aug. 18
				7-10		0	9	23	68	HC	5.8	0.10	2	8	211	156	105	51	
				10-43	40	0+	25	47	28	CL	5.4	0.40	1	3	45			ND	
L	Slx.a.-Antenn. lan.	9	N 10°	0-3	0	0+	33	43	24	L	4.9	0.40	2	13	211	102	78	24	Aug. 11
				3-20		6	30	42	22	L	4.6	0.10	0	4	31	48	22	26	
				20-35	28	58	25	17	0+	SL	4.9	0.10	0	3	24	15	5	10	
		9H		0-4	0	0+	20	62	18	SiL	4.8	0.30	0	10	178	67	52	15	Aug. 12
				4-10		0+	31	51	18	L	4.5	0.20	0	4	39	53	27	26	
				10-26		1	26	65	8	SiL	5.5	0.07	0	1	14	59	19	40	
				26-36	33	44	26	26	4	L	4.9	0.07	0	1	18	21	5	16	
(L)	Slx.a.-Ant.lan.	14A	SSW ND	0-42	0 -40	12	32	41	15	L	4.7	0.10	1	3	53	27	15	12	Aug. 31
(M)	Carex nigric.	14C		0-25	0 -20	20	23	39	18	L	5.2	0.10	0	6	113	25	13	12	Aug. 31
M	Carex nigric.	10	N 17°	0-3	0	3	32	49	16	L	5.0	0.30	0	21	261	57	33	24	Aug. 13
				3-33		15	28	49	8	SiL	5.1	0.10	0	3	20	50	14	36	
				33-41	35	45	23	31	1	SiL	4.9	0.07	0	9	18	25	6	19	
N	Salix nivalis	15W	NW (ND)	1-23	0	1	36	51	12	L	5.4	0.10	1	1	18	48	18	30	Sept. 4
				23-50+	23	3	31	61	5	SiL	6.0	0.10	0	1	16	40	8	32	
	UNVEGET-ATED	15U		0-18	2	2	32	34	32	CL	5.9	0.10	1	3	49	35	17	18	Sept. 4
				18-37	23	4	41	44	11	L	6.5	0.10	1	1	26	30	10	20	

(L) and (M) = like communities A and M, respectively, but vegetation not analyzed quantitatively

In #5B and #8B, B= terrace base

┐ indicates root extension through more than one horizon

N expressed as NO_3^-

P expressed as $P_2O_5^=$

K expressed as K^+

ND = no data

0+ = almost none

From coarsest to finest, the communities rank in the following order (coarse:fine): A (88:12), C (85:15), B (70:30), D (66:34), E (65:35), F (62:38), G (56:44), J and M (49:51), H (47:53 on the terrace top #8T), L (43:57), K (34:68). It should be pointed out that in the ridge-top community (D) the soil profile examined was very likely deeper and finer-textured than average for this site; several soil pit areas were abandoned because there were large rocks too near the surface to be able to obtain enough soil for later laboratory analysis.

Analyses of the 2 mm fractions of the mineral soils show that sandy soils, chiefly sandy loams, predominate under S slope communities, with the exception of the *Dryas* - graminoid community (B) which has sandy clay loam and loam soils. A much greater variety is found in N slope soils, with loams predominating and varying from a few sandy loams in areas of greater topographic exposure to a high clay soil in the very wet area (community K).

Pedogenesis has taken place slowly and the present soil mantle probably represents accumulation from weathered parent materials since the recession of Pleistocene ice, which scoured off earlier soil accumulation. Soil depth averaged 36 cm and exceeded 50 cm in only two of the 23 pits that were examined, one in a *Dryas*-dominated solifluction terrace top (Stand #8T) and the other under the *Salix nivalis* community (N, #15W).

In general, there has been greater development of soils on the N slope sites than on the S slope. Some of the factors which may contribute to this difference are:

(1) The S slope consists chiefly of arenaceous parent materials that are more resistant to weathering, whereas the N slope includes lenses of shale which weathers more readily.

(2) The more irregular topography of the N slope provides depressions for weathered materials to collect, whereas much of the S slope is more convex in profile, and being steeper the loose mineral particles would tend to move downward through gravitational and soil frost forces.

(3) Erosion by wind would be more intense on the windward S slope; the prevailing winds may pluck finer particles from this slope and redeposit them on the N (lee) slope.

(4) Fine windborne particles, e.g., loess, from other regions could be deposited the same way.

(5) Meltwaters would be produced more rapidly and with ordinary runoff would tend to move down the steeper S slope more quickly, thereby washing away finer particles.

(6) Although both slopes are subjected to congeliturbation, these processes are more pronounced on the N slope where more moisture is available from late snowmelt, resulting in more intense breakdown of parent materials.

(7) The greater amount of vegetation on the N slope

adds its effects to soil formation. Wind, low soil moisture, coarse texture and scree instability on the steep S slope all tend to inhibit vegetation establishment and soil development.

Depth of the Ah horizon varied from 4 cm at the *Dryas* - graminoid community (B, #13) to 20 cm at the *Cassiope mertensiana* - *Phyllodoce* (J, #8B) and *Salix arctica* - *Antennaria lanata* (L, #9) communities.

The parent materials of Signal Mountain soils consist almost entirely of non-calcareous shales, siltstones, sandstones and conglomerates, with some feldspathic quartzites originating in the glacial debris. No free lime was found in any of the profile samples. All the soil samples gave acid reactions, with pH values ranging from 4.5 in the hummock soil of the *Salix arctica* - *Antennaria lanata* community (L) to 6.5 in the bare area adjacent to the *Salix nivalis* community (N). The latter site is near the top of the Northwest Draw, a depression that has probably accumulated imported loess. Organic matter was usually associated with lower pH values; the slightly acid (pH 6.0 to 6.5) soils often had little or no organic matter. Thus, in general, S slope soils tended to have higher pH values than those of the N slope.

The amount of salts was extremely low in all soils, with conductivity ranging from 0.07 to 0.50 mmohs. Values for sodium were likewise low.

The available nitrogen (nitrate) content of almost all the soils was very low, with many soils showing none at all during the growing season when samples were taken. In two communities 21 ppm N was found in the uppermost horizons. This may have been due to the relatively early dates of soil collection (July 10 and 11) from these sites; perhaps the soil nitrogen reserves were not yet depleted as they were in other communities at later dates. The high values might also have been partly attributable to animal droppings which were noted, as some may have been included in the soil samples. Both these sites were released from snow early in the season and were therefore frequented by mammals and birds in search of food while other areas on the mountain were still under snow.

The phosphate content of the soils was also low, ranging from 1.0 to 20.5 ppm, with a mean of 4.4 for all horizons and a mean of 7.4 in the Ah horizons. Potassium values were very variable, ranging from 14 to 319 ppm and a mean of 74 in all horizons. In the Ah horizons the range was from 63 to 319 ppm with a mean of 138. The higher values of both phosphorus and potassium were generally from soils under communities with good moisture supply and consequent lush growth of vegetation.

Maximum root penetration ranged in depth from 17 cm in the *Dryas* - lichen community (D) of the ridge-top to 40 cm in the *Salix arctica* - *Arctagrostis* community (K) in

the very wet area and the *Carex nigricans* community in the snowpatch depression on the S slope (#14C). Since roots, particularly the fibrous types, spread laterally under the ground surface, they were found at depth even under unvegetated ground surfaces such as the scree soils (A, #7S and #4S), gravel tops of terracettes in the *Dryas - Empetrum* community (G, #11T), and the open patch at the *Salix nivalis* community (N, #15C).

Because most of the alpine terrain of Signal Mountain is sloped, drainage would be expected to be fairly rapid, particularly where the soils are coarse in texture. The soils on the S slope would not, therefore, tend to retain much moisture. However, on the N slope a constant supply of meltwater from snowpatches above tends to keep some areas wet during much of the summer. As a result, hummocks, stone nets, solifluction terraces and other forms of patterned ground are much more common on the N slope (see Plates 1, 17, 18, 20, 21). The greater the abundance of water, the more pronounced are these features.

The significant role of moisture is reflected in its correlation with the best developed and finest-textured soils. Several processes would be involved, such as: (1) water transport of fine mineral particles to areas of accumulation; (2) more intense cryoturbic processes which contribute to disintegration of parent materials through repeated freeze-thaw cycles; (3) chemical breakdown

of parent materials through processes such as oxidation. Fe_2O_3 accumulation on buried cobbles and as mottles was noted in soils of more moist areas, such as solifluction terraces (community J, #5B and #8B), the very wet *Salix arctica - Arctagrostis* community (K, #12), hummocks in the *Salix arctica - Antennaria lanata* community (L, #9H), and the *Carex nigricans* meadow(M, #10). The presence of iron in the rocks of Signal Mountain has resulted in reddish soils, especially in B horizons, ranging from a few 2.5 YR and 7.5 YR to many 10 YR in hue. Glei was found in the very wet soil of the *Salix arctica - Arctagrostis* community (K).

The highest moisture retention values at both 1/3 and 15 atmospheres tension, taken as Field Capacity (FC) and Permanent Wilting Point (PWP) percentages respectively, were found in the highly organic uppermost horizons of the *Salix arctica - Arctagrostis* community (K: 156 and 105) and at solifluction terraces, including the *Dryas*-dominated terrace top (#8T: 156 and 106) and the terrace base *Cassiope mertensiana - Phyllodoce* community (J, #8B: 149 and 116).

Available moisture values (i.e., FC - PWP), based on oven dry weights of the smaller than 2 mm fraction, ranged from 4 to 22% in S slope soils (9 to 22% in the root zones of communities A and B respectively) and 10 to 53% (14 to 53% in the root zones of communities E and J respectively) in N slope soils.

Comparison of field moisture amounts in soil samples collected in 1967 and 1968 from 2.5, 10 and 25 cm depths indicates a general presence of considerably more moisture in 1968 (Table 12). A higher amount of rainfall was received and lower temperatures prevailed during August, 1968.

In the upper 2.5 cm the 1968 values are higher, ranging from a negligible 0.1% in scree to 36.5% at the *Dryas* - graminoid community (B), in all but the *Dryas* - *Kobresia* community (C); the latter is probably due to sampling error.

At 10 and 25 cm depths about one-third of the profiles showed less moisture in the 1968 soil samples. All these were from N slope communities located below late-lying snowpatches. Higher moisture content in 1967 was probably related to (1) a greater accumulation of snow due to a higher than normal snowfall during the preceding winter, and (2) higher than normal temperatures in late summer which would cause more rapid melting of snowpatches and consequent downslope seepage of meltwaters.

At 2.5 and 10 cm depths the largest difference (36.5% higher in 1968) was found in the *Dryas* - graminoid community (B). The 1967 samples were collected after a 12-day rain free and very warm period. At the 25 cm depth the 1968 moisture was 21.5% greater at the *Dryas* - lichen community (D) on the ridge top and 28.3% greater in the hummock profile (#9H) of community L on the N slope.

TABLE 12. SOIL MOISTURE IN WHOLE SOILS FROM SIGNAL MOUNTAIN ALPINE TUNDRA.

PIT	COMM-UNITY	DEPTH (cm)	1967 DATE	DAYS SINCE PRECIP.	% MOISTURE (O.D. BASIS)	% MOISTURE IN 1968*
7S	A	to 2½	July27	3	3.4	5.9
		10			7.7	15.7
		25			8.4	
4S	A	to 2½	July 18	4	7.2	7.3
		10			23.3	23.0
		25			15.7	15.3
7V	A	to 2½	July 27	3	16.5	27.1
		10			12.6	18.4
		25			7.9	9.7
4V	A	to 2½	July 18	4	8.1	37.5
		10			13.7	16.8
13	B	to 2½	Aug.19	12	11.7	86.9
		10			14.8	36.9
		25			13.8	15.0
1	C	to 2½	July 10	1	61.6	57.1
		10			25.0	29.1
		25			12.3	22.7
6	D	to 2½	July 26	½	74.3	184.1
		10			12.3	71.2
		25			13.5	50.2
2	E	to 2½	July 11**	1	126.5	230.9
		10			48.3	43.3
		25			21.1	18.3
3	F	to 2½	July 17	3	81.6	83.5
		10			46.1	83.6
		25			33.3	15.8
11D	G	to 2½	Aug.16	9	60.5	126.4
		10			54.4	33.2
		25			29.4	25.4
11E	G	to 2½	Aug.15	8	58.1	121.4
		10			18.3	37.5
		25			10.6	29.2
11T	G	to 2½	Aug.15	8	11.3	15.4
		10			14.0	18.9

*All samples collected on August 15, 1968, after several weeks of intermittent rain.

** Snowbanks still melting above site on this date.

TABLE 12 (cont'd.)

PIT	COMM-UNITY	DEPTH (cm)	1967 DATE	DAYS SINCE PRECIP.	% MOISTURE (O.D. BASIS)	% MOISTURE IN 1968
8T	?H	to 2½	Aug.9	2	139.8	215.4
		10			46.8	39.5
		25			19.7	20.9
		50			17.5	
5B	J	to 2½	July 19	½	217.1	222.5
		10			35.5	24.4
		25			20.0	15.9
8B	J	to 2½	July 29	5	239.3	248.2
		10			112.7	105.1
		25			21.2	18.6
12***	K	to 2½	Aug. 18	11	564.8	
		10			529.6	
		25			69.4	
9	L	to 2½	Aug. 11	4	181.2	185.1
		10			54.0	74.5
		25			15.3	20.7
9H	L	to 2½	Aug. 12	5	96.3	91.9
		10			105.1	77.7
		25			26.0	95.5
14A	(L)	to 2½	Aug. 31	4	25.7	89.1
		10			19.2	42.9
		25			12.0	15.6
14C	(M)	to 2½	Aug. 31	4	43.9	50.7
		10			21.5	27.3
		25			31.7	31.7
10	M	to 2½	Aug. 13	6	86.1	91.4
		10			69.1	72.8
		25			83.4	56.9
15W	N	to 2½	Sept. 4	1	68.1	74.0
		10			52.4	63.1
		25			42.8	35.4
15C		to 2½	Sept. 4	1	21.5	33.2
		10			33.5	28.0
		25			16.2	29.1

*** Saturated moss only, no mineral soil, to 10 cm depth.

A seeming anomaly was noted in the *Dryas* - *Empetrum* community (G) where the pit under *Dryas* (#11D) had 10.3% less moisture at 10 cm and 2.5% less at 25 cm in 1968, while the pit under *Empetrum* (#11E) had 11.8% more at 10 cm and 13.0% more at 25 cm in 1968. A much coarser, gravelly soil under *Empetrum* coupled with an 8-day rain free period in 1967 resulted in much lower moisture retention than that of the finer soil under *Dryas*. In 1968 the moisture contents of the two profiles were very similar.

Taking samples from both years into consideration and excluding the very wet site at the seepage spring (community K, #12), the moister profiles were those associated with solifluction terraces (communities J and H, #8B, #5B and #8T) and hummocky ground (*Dryas* - moss, E, #2, and *Salix arctica* - *Antennaria lanata*, L, #9 and #9H, communities). The best developed soil profiles were also found at these sites (e.g., Plate 8).

Permafrost was not found on Signal Mountain. Frozen ground was encountered only at the edges of snowpatches on June 4, 1967. It is expected that the most intense congeliturbation takes place during the alpine spring and autumn.

PLATE 8. One of the better developed alpine soils on Signal Mountain, at the base of a solifluction terrace (#5B) on the N slope. The Ah horizon is about 12 cm thick.

(Photographed August 15, 1968).

FLORA

A total of 271 plant taxa was collected from the alpine zone of Signal Mountain. This included 68 families, 144 genera and 267 species. Of these, 31 families, 83 genera and 157 species were vascular plants; 25 families, 38 genera and 57 species were bryophytes; 12 families, 23 genera and 53 species were lichens (complete list in Appendix I). It is expected that the collections of bryophytes and lichens are not nearly so complete as that of the vascular plants due to the author's inexperience with the two former groups. Although fungi and algae were present (one species of *Nostoc* was common), they were not included in this study.

Among vascular plant families the Compositae had the largest representation with 22 species, Cyperaceae ranked second with 14 species, and Gramineae and Ericaceae were each represented by 12 species.

About 30% of the vascular species found on Signal Mountain have a Cordilleran distribution, i.e. they are restricted to the mountains of western North America. Examples are *Salix nivalis, Cassiope mertensiana* and *Antennaria lanata*. A larger proportion, about 45% of the species, has an arctic-alpine distribution. Some of these occur in circumpolar tundra areas, e.g. *Kobresia bellardii, Sibbaldia procumbens* and *Artemisia norvegica*, but some are only found on this continent, e.g. *Cerastium beeringianum*,

Gentiana prostrata and *Solidago multiradiata* (all above data based on Hultén 1968). The eight species not described by Moss (1959) - *Carex macrochaeta, Luzula arcuata, Ranunculus gelidus, R. nivalis, Potentilla hyparactica, P. villosa, Pedicularis oederi, Antennaria monocephala* - were identified through keys on arctic floras.

Many of the bryophytes and lichens growing on Signal Mountain are widely distributed throughout the world, e.g. *Pohlia cruda, Tortella tortuosa* and the *Polytrichum* species. Some of the species are rare in the Rocky Mountains of Alberta, such as *Hypnum procerrimum* and *Solorina octospora,* having a discontinuous distribution here. One Signal Mountain moss collection, *Brachythecium turgidum*, was the first recorded in Alberta (Bird, pers. comm.).

Growth Forms

Subalpine tree species were found in krummholz form in a number of protected sites in the alpine zone of Signal Mountain. *Picea engelmannii* was found growing at higher elevations than *Abies lasiocarpa* on all slopes. The other krummholz species, *Pinus contorta*, was scarce and found only on the S slope at a maximum elevation of about 2173 m (7130 ft.) where both *Abies* and *Picea* still had supranival flagging forms. The line of continuous growth of trees was from 40 to 70 m higher on the S slope than on the N slope. However, krummholz was observed about 60 m higher on the N than on the S slope (elevation

about 2250 m compared with 2190 m). The occurrence of krummholz at higher elevations on the N slope is probably related to the topographic protection afforded on this slope.

Dwarf shrubs are the dominant vascular growth-form group on Signal Mountain. Most of the low shrubs were found to grow in spreading mats: *Dryas hookeriana, Salix arctica, S. nivalis, Vaccinium vitis-idaea, Empetrum nigrum, Arctostaphylos rubra, A. uva-ursi* and *Juniperus communis.* Several low shrubs grow in tufts: *Cassiope tetragona, Vaccinium scoparium* and *Potentilla fruticosa,* while *Cassiope mertensiana, Phyllodoce glanduliflora* and *P. empetriformis* combine the two growth forms by producing tufted mats. Only four shrubby species had a more-or-less erect growth habit: *Salix alaxensis, Kalmia polifolia* and *Ledum groenlandicum.* All these were found low on the N slope, as was *Vaccinium scoparium,* and were uncommon, poorly developed, and smaller in size than the respective plants occurring in subalpine areas. *Arctostaphylos uva-ursi, Juniperus communis* and *Potentilla fruticosa* were found only at very local sites low on the S slope.

Several species of herbaceous plants were also found growing in mats or cushions: *Selaginella densa, Equisetum scirpoides, Carex nigricans, Arenaria sajanensis, Silene acaulis, Astragalus alpinus, Saxifraga bronchialis, S. oppositifolia* and *Antennaria alpina.*

A large number of herbaceous species have a tufted or tussock growth habit. This includes most grasses and sedges, *Lycopodium* species, *Anemone drummondii, Potentilla nivea, Oxytropis podocarpa, Cardamine bellidifolia, Draba nivalis* and others.

The rosette growth form was also common, particularly on dry, gravelly or scree sites. Typical of this form are: *Androsace septentrionalis, Crepis nana, Saussurea densa* and *Taraxacum lyratum.* Many plants which grow singly and have an erect form have basal rosettes of leaves. This is true of most *Saxifraga* species, *Gentiana glauca, Campanula lasiocarpa* and others.

In describing plant community structure in following sections the term "compact growth form" includes mat, tuft, cushion and rosette forms.

The final group of vascular plants includes those that grow singly, are erect or ascending, and have stem leaves. The comparatively large number in this group includes *Anemone parviflora, Veronica alpina, Castilleja* spp., *Pedicularis* spp., *Arnica alpina, Artemisia norvegica* and others.

Half of the dwarf shrub species growing on Signal Mountain are evergreens: *Cassiope* species, *Phyllodoce* species, *Empetrum nigrum, Arctostaphylos uva-ursi* and *Kalmia polifolia.* Of the herbaceous plants, only species

of the Pteridophyta are evergreen: *Lycopodium* species, *Selaginella densa* and *Equisetum scirpoides* (stems).

All but three species of the alpine flora of Signal Mountain are perennial: *Gentiana prostrata* is a biennial, and *Androsace septentrionalis* and *Gentianella propinqua* may be annual or biennial.

VEGETATION

Fourteen plant community types, some more distinct than others, were recognized in the alpine zone of Signal Mountain. A "community type", as used here, refers to a plant community with a fairly definite vegetation structure and species composition, occurring in areas with a fairly specific combination of environmental factors, i.e., "habitat type", and which would be expected to recur wherever an equivalent combination of these factors prevails (Daubenmire, 1968). Intermediates between the recognized community types are common on Signal Mountain and it was necessary to take this into account both in the vegetation analysis and interpretation of results. If the continuum concept of vegetation is accepted, and it is here, then it becomes a question of arbitrarily delimiting the boundaries, but in an ecologically meaningful manner. The evaluation of community status was, therefore, made subjectively in the field.

As noted in Methods, few communities were sampled in duplicate, and it should thus be stressed that data for most of the communities are from single representative stands. Although the cover and frequency of dominant species would probably be of similar accuracy, those for subordinate species, particularly the rare ones, would be expected to be less accurate in each of the community types.

In comparing the N and S slopes, the N is

more gentle and has about twice the area of the S slope, as well as much greater topographic diversity. As a result, about three times as many communities were sampled and/or described for the N slope.

The vegetation of the N slope presents a mosaic pattern based chiefly on local topographic differences which in turn influence the other environmental factors. The communities here were found to be highly correlated with the date of snow release and the amount of soil moisture present during the growing season - the latter largely dependent, directly or indirectly, on the former.

One community was sampled on the main ridge. This was the longest stand, 91.5 m (300 ft.) in length. Both N and S elements are represented here due to microtopographic effects.

No sampling was done on the W slope because of the heterogeneity of the vegetation caused by (a) the unevenly steep slope, (b) much outcropping rock, and (c) the highly variable macro- and microtopography. Although *Dryas hookeriana* was the dominant species, this slope did have several species not found elsewhere on Signal Mountain, namely *Salix vestita, Arctostaphylos rubra* and *Purola grandiflora*. *Hedysarum alpinum* was only present here and on the SW slope.

Because the E end of Signal was rather distant from

field headquarters and beyond much wet terrain, only a cursory examination of it was made on a few occasions. In general, the vegetation was *Dryas*-dominated and appeared to be a dry, transitional type between that of the protected portions of the S and N slopes.

Description of Plant Communities

Since a variety of growth forms is represented in the vegetation, it was felt that neither cover nor frequency could be considered alone to show the relative importance or role of a species in a community. A large, spreading plant may have a high cover value, but low frequency in sampling plots. Conversely, a small, upright plant would invariably have a small cover value, but its frequency may be high. Consequently, a Prominence Value, as proposed by Beals (1960) and modified by La Roi (1964), was calculated for each species in a stand by multiplying its mean cover by the square root of its frequency: $PV = C\% \sqrt{F\%}$.

The naming of each community was based on the two species or plant groups having the highest Prominence Values. It might be noted that species names have been omitted in several community names for convenience. A species name is used only when more than one member of a genus was found on Signal Mountain.

Using the Prominence Values of 94 vascular species, indices of vegetational similarity between the twelve

sampled communities were calculated. This index is based on the Coefficient of Community proposed by Czekanowski (1913), then by Sørensen (1948), and is widely used by ecologists today. The formula, as used, is

$$I_{sim} = \frac{2w}{a+b} \times 100$$

where a = the sum of Prominence Values of all species in one stand,

b = the sum of Prominence Values of all species in another stand,

w = the sum of the lesser Prominence Values for those species present in both stands,

I_{sim} = the Index of Similarity, expressed as a percentage.

The actual computations were made by the IBM System 360/67 at the University of Alberta Computing Science Centre, using the program developed by Ream (1962) and modified by J.E. Purchase and R.J. Hnatiuk (Department of Botany, University of Alberta).

A matrix of Indices of Similarity was constructed so that the relationships of the communities to each other could be shown, and the order of communities subsequently arranged so that similar communities were close to each other in the final matrix. Identifying letters (A,B,...M) were then assigned to the communities according to their positions in the final matrix (Table 13). The community descriptions in the next section follow this order.

TABLE 13. INDICES OF SIMILARITY BETWEEN ALPINE PLANT COMMUNITIES ON SIGNAL MOUNTAIN (EXPRESSED AS PERCENTAGES).

	SOUTH SLOPE			NORTH SLOPE								
COMMUNITY	A	B	C	D	E	F	G	H	J	K	L	M
A	-	41.0	45.0	49.7	40.3	35.4	28.8	30.9	1.4	1.4	2.1	0.1
B	41.0	-	41.0	55.6	54.6	32.9	42.1	39.3	7.7	10.9	10.0	0.7
C	45.0	41.0	-	73.7	65.9	30.3	46.6	30.3	2.8	1.2	1.6	0.1
D	49.7	55.6	73.7	-	72.0	34.9	46.9	30.8	2.4	3.0	3.4	0.5
E	40.3	54.6	65.9	72.0	-	41.7	52.6	39.2	7.2	9.4	13.1	1.0
F	35.4	32.9	30.3	34.9	41.7	-	30.6	36.5	8.5	11.4	13.1	0.9
G	28.8	42.1	46.6	46.9	52.6	30.6	-	46.0	15.2	21.7	18.7	0.7
H	30.9	39.3	30.3	30.8	39.2	36.5	46.0	-	34.6	31.8	38.5	4.0
J	1.4	7.7	2.8	2.4	7.2	8.5	15.2	34.6	-	20.1	29.7	4.3
K	1.4	10.9	1.2	3.0	9.4	11.4	21.7	31.8	20.1	-	38.5	2.4
L	2.1	10.0	1.6	3.4	13.1	13.1	18.7	38.5	29.7	38.5	-	8.7
M	0.1	0.7	0.1	0.5	1.0	0.9	0.7	4.0	4.3	2.4	8.7	-
TOTAL	276.1	335.8	338.5	372.9	397.1	276.2	349.9	361.9	133.9	151.8	177.4	23.4
MEAN	25.1	30.5	30.8	33.9	36.1	25.1	31.8	32.9	12.2	13.8	16.1	1.1

An almost linear relationship between communities was noted when the highest I_{sim} value for each pair was considered. Communities could be ranked in the order shown below (Fig. 14).

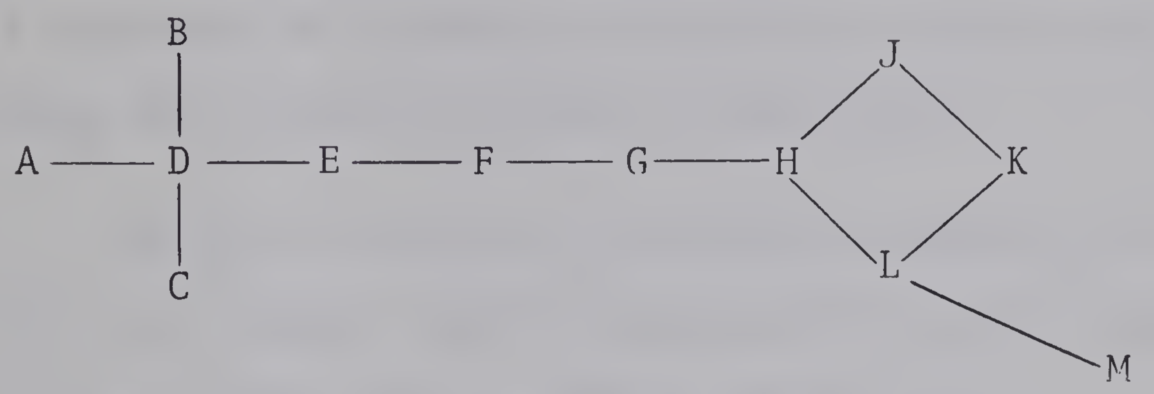


FIGURE 14. VEGETATION GRADIENT SHOWING RANK RELATIONSHIPS BETWEEN SIGNAL MOUNTAIN ALPINE PLANT COMMUNITIES BASED ON HIGHEST INDICES OF SIMILARITY WITH EACH OTHER.

The communities have been named as follows:

A = *Dryas* islands on scree (S slope)

B = *Dryas* - graminoid community (S slope)

C = *Dryas* - *Kobresia* community (SW slope)

D = *Dryas* - lichen community (ridge top)

E = *Dryas* - moss community (N slope)

F = *Cassiope tetragona* - *Dryas* community (N slope)

G = *Dryas* - *Empetrum* community (N slope)

H = *Dryas* - *Salix arctica* community (N slope)

J = *Cassiope mertensiana* - *Phyllodoce glanduliflora* community (N slope)

K = *Salix arctica* - *Arctagrostis* community (N slope)

L = *Salix arctica* - *Antennaria lanata* community (N slope)

M = *Carex nigricans* community (N slope)

The three communities with the highest Indices of Similarity with each other (Table 13) are all located near the W end of Signal Mountain, yet each has a different aspect. Community D is on the ridge top, C on the SW slope and E on the N slope. All three communities would be expected to accumulate relatively little snow in winter since the prevailing wind is from the W.

The most distinctly different community is the *Carex nigricans* meadow which consistently had the lowest indices of similarity with the other communities.

ALPINE PLANT COMMUNITIES

A. *DRYAS* ISLANDS ON SCREE

Habitat Description

Open scree is a feature of at least half the S slope of the main ridge. The scree consists chiefly of brown shale fragments which impart their colour to the slope. Where quartzitic fragments are mixed with the shale lighter coloured stripes occur on the brown (Plate 9). Although the bedding dips about 30°, the products of mass wasting have moved down unevenly, giving the slope a somewhat variable angle.

Vegetation has stabilized some of the scree, especially on the lower portion of the slope. However, a considerable amount of mass movement is still taking place, particularly in spring and autumn when diurnal needle ice action is more intense, causing vegetation patterns on the scree. Where the slope is more gentle near the top of the ridge, vegetation islands are circular or nearly so. As the slope angle increases the islands become elongated downslope to form vegetation stripes. Below the region of vegetation stripes the slope angle lessens due to the accumulations of wastage material. This permits more continuous vegetation, usually with stone (scree) stripes running downslope through it (Plate 9).

PLATE 9. The main ridge of Signal Mountain and its S slope, showing vegetation islands on the upper portion of the slope which elongate downslope to form vegetation stripes lower down. Still lower there is a more continuous vegetation cover with stone stripes running downslope through the vegetation. The vegetation is dominated by *Dryas hookeriana*.

(Photographed July 28, 1967).

The upper portion of the scree area does not have much snow cover in winter because prevailing winds from the W to SW sweep across this slope with its SW aspect. Snow release, therefore, comes relatively early. Among the earliest flowering dates were those recorded here, with a peak number of species in anthesis during the last week in June in 1967. Because of the aspect, much direct beam solar radiation is received by this slope, and the slope winds in addition to the horizontal winds all tend to promote a high potential evapotranspiration.

The microenvironmental station (ME-2) located in this general area recorded the highest air and soil temperatures, particularly above and under bare scree. The highest wind velocity was also recorded here, with gusts to 72 km/hr (45 mph). (This value was greatly exceeded on other days when it was impossible to take a reading with the Deuta anemometer.)

Two areas were sampled. Stand #7 was located on a 12° slope of predominantly shale scree, about 15 m below the ridge summit, at an elevation of 2245 m. The vegetation was mostly in mats forming definite islands, many of which were elongated downslope (Plate 10). Stand #4 was located on a slightly steeper slope (14°), with the vegetation islands tending to run into each other to form stripes on the lighter coloured quartzitic scree. This stand was about 15 m lower in elevation and a few hundred metres to the west of #7.

PLATE 10. Dryas islands on shale scree, high on the S slope of Signal Mountain.
The many scattered boulders are chiefly quartzite and were probably imported by Pleistocene glaciation. Vegetation establishment appears to be enhanced by the boulders as the islands often spread upslope, which is the lee side of the boulders on the S slope.
On N slope scree the islands tend to spread downslope, which is the lee side on that slope.
(Photographed July 27, 1967).

Both stands have very coarse surface materials but Stand #7, whose site is less steep, has a much larger number of cobble-sized and larger stones with the scree. These larger stones have a high lichen cover indicating that they are not so subject to congeliturbation as are the flatter and relatively lichen-free scree fragments.

Soil pits were dug in vegetated and bare scree in each stand. The soil textures were among the coarsest in the alpine zone of Signal Mountain. All four profiles had gravelly sandy loams with cobbles throughout, and the available moisture values were all low.

Although the bare scree surface is relatively unstable, roots extend under it from the vegetation islands in both stands. At depths greater than 8 cm all profiles had similar root content, with roots extending to 23 and 25 cm.

Vegetation

Vegetation cover was about 20% in each stand and floristic compositions were also similar in the two. It was therefore decided to treat these as stands of the same community type and combine the data. The total area represented by the two stands was 1064 m^2 (11,450 ft^2).

In spite of a high potential evapotranspiration and a low cover of vegetation, this community has a higher species diversity (64) than the average for Signal Mountain's alpine communities (53), and was exceeded only at the summit ridge

community to which it is most similar. This high number is due, in part, to the lichen diversity (23) which is the highest of any community.

TABLE 14. PHYSIOGNOMY OF *DRYAS* ISLANDS ON SCREE

	% COVER POINTS	% QUADRAT FREQUENCY	PROMINENCE VALUE
Total Vascular Plants (31 spp.)	21	100	210.0
Dwarf Shrubs	16	80	143.7
Compact Forbs*	4	95	38.9
Single-growing Forbs	2	65	16.1
Graminoids	1	60	7.8
Bryophytes (10 spp.)	2	35	8.9
Lichens (23 spp.)	6	100	60.0
Terricolous	4	50	28.3
Saxicolous	2	85	18.4
Open Scree and Rock	74	100	723.8

* cushions, rosettes, mats, tufts

The vascular flora shows a preponderance of chionophobous species with adaptations to conserve moisture and heat, including compact growth forms in both dwarf shrubs and forbs (Tables 14, 15), small leaves with thick cuticles and/or epidermal hairs.

Dryas hookeriana is the dominant plant cover on scree, spreading by prostrate and much branched woody stems and forming rather dense mats that enable other species to become established. The elongated islands of these mats are maintained by the downward movement of unstable scree adjacent to them.

TABLE 15. SPECIES STRUCTURE OF *DRYAS* ISLANDS ON SCREE

SPECIES	% COVER SCALE	% COVER POINT	% QUADRAT FREQUENCY	PROMINENCE VALUE
VASCULAR PLANTS:				
Dwarf shrubs				
Dryas hookeriana	12.5	13.0	60	99.15
Salix nivalis	2.0	2.5	68	18.55
Forbs with compact growth form				
Oxytropis podocarpa	1.2	2.0	61	12.50
Selaginella densa	1.8	2.0	34	11.08
Antennaria alpina	1.0		17	4.12
Potentilla nivea	0.7		32	3.96
Ranunculus gelidus	0.2		10	0.63
Silene acaulis	0.1		8	0.28
Anemone drummondii	0.1		5	0.22
Saussurea densa	0.1		4	0.20
Arenaria sajanensis	0.1		2	0.14
Draba nivalis	0.1		2	0.14
Taraxacum lyratum	0.1		2	0.14
Arenaria rossii	T*		0	
Crepis nana	T		0	
Erigeron compositus	T		0	
Oxytropis campestris	T		0	
Forbs growing mostly singly				
Campanula lasiocarpa	0.6	0.5	34	3.50
Myosotis alpestris	0.4	0.5	25	2.25
Polygonum viviparum	0.5		20	2.24
Campanula uniflora	0.3		15	1.16
Arnica alpina	0.2		12	0.69
Gentianella propinqua	0.2		12	0.69
Solidago multiradiata	0.2		8	0.57
Stellaria monantha	0.1		15	0.39
Potentilla diversifolia	0.1		8	0.28
Artemisia norvegica	T		2	
Gentiana prostrata	T		2	
Graminoids				
Festuca baffinensis	0.4	0.5	15	1.74
Carex drummondiana	0.2		15	0.77
Other sedge spp.	0.3		40	1.90
Agropyron latiglume	0.1		5	0.22
Poa alpina	0.1		5	0.22
Luzula spicata	T		2	

TABLE 15. Cont'd.

SPECIES	% COVER SCALE	% COVER POINT	% QUADRAT FREQUENCY	PROMINENCE VALUE
BRYOPHYTES:				
Bryum stenotrichum				
Dicranum fuscescens				
Encalypta rhaptocarpa				
Hypnum revolutum				
Orthotrichum sp.				
Polytrichum juniperinum				
Rhacomitrium lanuginosum				
Rhytidium rugosum				
Tortella fragilis				
Tortula ruralis				
LICHENS:				
Alectoria nitidula				
A. ochroleuca	0.2		15	0.77
A. pubescens				
Caloplaca jungermanniae				
C. stillisideorum				
Candelaria aurella				
Cetraria cucullata	0.4	0.5	45	3.02
C. islandica	0.2		12	0.69
C. nivalis	0.4	0.5	40	2.85
C. tilesii	0.5		30	2.74
Cladonia pocillum	0.4		12	1.39
Cornicularia aculeata	0.3		33	1.92
Dactylina ramulosa				
Hypogymnia intestini-formis				
Lecanora polytropa				
Ochrolechia uppsalien-sis				
Omphalodiscus kraschen-innikovii				
Peltigera canina var. *rufescens*				
P. malacea	0.4		15	1.55
Physcia muscigena				
Rhizocarpon geographicum				
Stereocaulon alpinum				
Thamnolia subuliformis				

* T = Trace

Another abundant species is *Salix nivalis* which spreads by prostrate stems that often become buried. This dwarf willow is very common among the *Dryas* mats, as well as on them, but does not itself form extensive mats here.

In the very uppermost portion of the scree, where the topography is somewhat more convex and neither *Dryas* nor *Salix nivalis* have become established, species that grow in cushions (e.g., *Silene acaulis*), tufts (*Anemone drummondii*), and rosettes (*Crepis nana*) are more common. Like the mat-forming dwarf shrubs, these species may also add their effects to some scree stabilization.

It was noted that not all species require the presence of a vegetation mat for establishment on scree. About half of those growing on bare scree between *Dryas* mats have a dense or compact growth form. All species that grow singly on bare scree, including *Arnica alpina, Campanula lasiocarpa, Campanula uniflora, Myosotis alpestris, Agropyron latiglume* and *Poa arctica*, are slightly pubescent to densely villose.

Species which appear to require a vegetation mat for establishment are *Selaginella densa, Carex drummondii* and other *Carex* spp., *Luzula spicata, Arenaria sajanensis, Polygonum viviparum, Gentiana prostrata, Gentianella propinqua, Artemisia norvegica* and *Potentilla diversifolia*. The two latter species were only found in the lower stand (#4) and did not have the vitality of plants of the same species growing in more mesic habitats.

It was particularly noted that grass species grew on bare scree whereas *Carex* species appeared to establish only on mats or cushions of other species.

Mosses were much less prominent than lichens and were chiefly associated with vascular species mats and cushions.

Some scree is also present near the top of the north slope, just over the ridge from the two stands studied. The slope angle is small, well under 10°, and the *Dryas* - dominated islands of vegetation differ from those on the south slope in that north slope species, e.g., *Pedicularis lanata*, grow here. This area was not sampled. It is expected that the vegetation of this area would lie somewhere between communities A and D in the vegetation gradient (Fig. 14).

AA. CUSHION PLANT COMMUNITIES OF ROCK CREVICES

Habitat Description

A relatively small proportion of Signal Mountain has exposed bedrock supporting crevice vegetation. The rock face immediately below the fire lookout and above the west rock slide (Figs. 2,3) was studied qualitatively. A list of species was made but no soil samples were collected from the crevices as the amounts would be too small for analysis.

The rock face consists chiefly of sandstone and dips SW at an angle of about 30°; it is the dip face from which strata had broken away to form the rock slide. Although meteorological data were not obtained on the rock face, it would be expected that this would be a warm, windy and very dry site during the summer.

With exposure to prevailing horizontal winds, slope winds and a maximal amount of insolation, little snow can accumulate and remain here until the vernal season, except in crevices. Snow, therefore, is gone early in the year and the rocks absorb much solar radiation. Consequently, the plants growing here were in anthesis earlier than elsewhere on the mountain, preceding those of the scree communities by two to four days in 1967.

Vegetation

Dwarf shrubs were nearly absent from the crevice vegetation, but the vascular species composition here was otherwise more like the communities on scree, particularly the high scree areas, than like any other community type. Although the habitat is more stable than scree, it is more xeric and, therefore, this community might be considered a more extremely chionophobous phase of community A, resulting from the more harsh climatic conditions prevailing here.

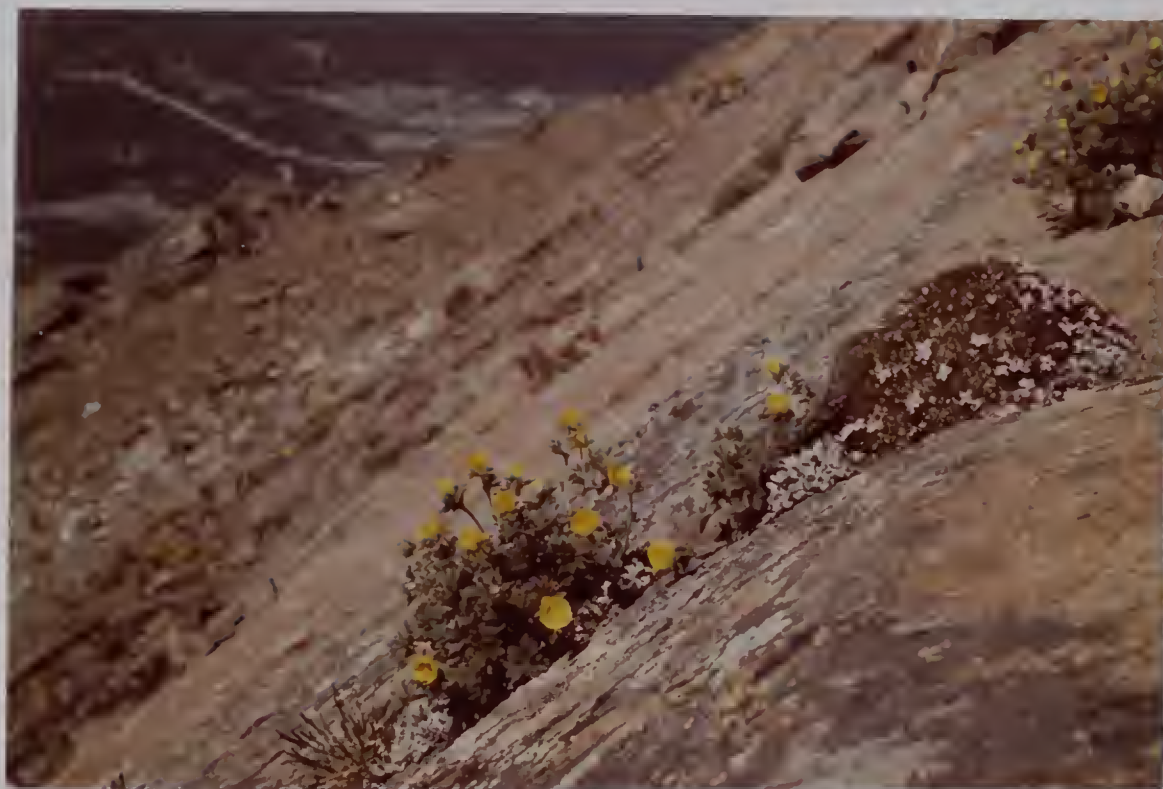


PLATE 11. Cushions of *Potentilla nivea, Silene acaulis, Antennaria alpina* and *Trisetum spicatum* growing out of crevices on the rock face below Signal Mountain Fire Lookout.

(Photographed June 24, 1967).

Lichens are the first plant colonizers of rock faces and other stationery rock because of two factors: (a) their ability to penetrate and extract mineral nutrients from the surface layers of rock, as well as from air, and (b) their ability to withstand dessication. Typical of these saxicolous lichens, which were found on this rock face, are *Rhizocarpon geographicum*, *Omphalodiscus krascheninnikovii*, *Umbilicaria hyperborea*, *Lecanora polytropa*, *Alectoria pubescens*, and several *Caloplaca* species. Judging from the size of trees growing on the slide area below (La Roi, pers. comm.) and the high lichen cover on the rock surfaces, the main rock slide took place at least several hundred years ago. Two fruticose lichens, *Cetraria cucullata* and *C. nivalis* occasionally grow on crevice soil of the rock face. Mosses were rare at this site and when present were found in more protected and shaded locations.

Only a small number of vascular species are able to inhabit this rock crevice environment. They are all early flowering species, an essential adaptation in any habitat that becomes dessicated early in summer. Another feature common to these species is their caespitose growth (Plate 11). This cushion growth habit tends to inhibit excessive moisture loss.

The vascular species found below the fire lookout were *Potentilla nivea*, *Silene acaulis*, *Saxifraga bronchialis*, *Anemone drummondii*, *Draba incerta*, *D. nivalis*, *Antennaria*

alpina, Erigeron compositus, Agropyron latiglume, Festuca baffinensis, Trisetum spicatum, Carex drummondiana, Selaginella densa, and occasionally *Oxytropis podocarpa.* Most of these species have strongly pubescent stems and leaves. Those with somewhat glabrous leaves, e.g. *Silene acaulis, Saxifraga bronchialis* and *Selaginella densa*, have small, tough, and densely matted or tufted leaves. Another glabrous species with small, closely packed leaves, *Saxifraga oppositifolia*, was found where early meltwaters were seeping through the crevices and creating a more moist environment than was apparently required by the other species. *Dryas hookeriana* was rare and the plants were small.

Rock piles were not investigated to any extent, but the fern *Cystopteris fragilis* was noted between boulders. This species was not found in any community type investigated more fully.

B. *DRYAS* - GRAMINOID COMMUNITY

Habitat Description

Patterned ground is a prominent feature of the S slope site where this community type was studied (Stand #13). Gravelly nonsorted stone stripes form a very uneven pattern through the predominantly vegetated area (Plate 12), indicating the presence of adequate amounts of water for intensive frost action during some portions of most years.

PLATE 12. Patterned ground at the *Dryas* - graminoid community toward the E end of the S slope of Signal Mountain, as seen from an upslope location.

The south snowpatch depression, shown in Plates 30 and 31, is at the right centre of the photograph.

(Photographed August 19, 1967.)

This type of patterned ground is common at the SE to E end of Signal Mountain (see Plate 1).

The sampled community was located below the saddle (see Figs 2,3) at an elevation of about 2243 m (7360 ft). The stand area was 465 m^2 (5000 ft^2) and appeared somewhat flattened when compared with the slope above the stand and below the saddle. The slope angle of the stand was 13° and the aspect due south.

Although not too much snow would be expected to accumulate at the stand site, snow does accumulate to a considerable depth in the saddle, which is sheltered from prevailing winds, and probably persists into July most years. After heavy summer snowstorms, such as those of July 21, 1967, June 30, 1968, and August 5, 1969, when a considerable amount of snow accumulated, small seepage springs were found trickling all over the usually dry slope immediately below the saddle. The sporadic supply of water during the warmer months of the year is no doubt one of the factors contributing to the distinctive community at this site as compared with communities A and C.

Station ME-3 was located a very short distance above this stand. It showed this area to be the second warmest measured; both air and soil temperatures were exceeded only at the scree station. Wind velocity was greater at the scree and summit stations. It would be expected that slope winds

would often account for more of the air movements than would horizontal winds since some topographic protection is afforded by the central and westernmost portions of the mountain.

Peak anthesis occurred only two to three days later than in the scree community for species common to both areas. However, late and/or long-blooming species such as *Gentiana prostrata* and *Polygonum viviparum* were more abundant here and the blossoming period of these extended well into August.

The substrate of this plant community is a gravelly clay loam including a large number of rock fragments ranging in size from gravel to small boulders. The soil of the unvegetated area is even coarser with larger rock fragments distributed throughout the profile. Roots extended to a depth of 20 cm under vegetation, with only occasional roots extending out under the stone stripe area.

Some leaching has apparently taken place so that the pH of the poorly developed B horizon was 5.9 while that of the thin Ah horizon was 6.3. At the time of sampling, on August 19, 1967, the soil was dry and extremely hard since warmer weather had prevailed for twelve preceding days. Mechanical analysis later showed a higher proportion of fines than in the scree soils and this was reflected in considerably higher available moisture values than in community A. The nutrient status of the two, however, was very similar.

Vegetation

Vascular and bryophyte species diversities in the *Dryas*-graminoid community are similar to those of the scree community. However, the total number of 52 is lower since only half the number of lichen species were present here (Table 16).

Bryophytes (mosses only) are more common in this community than in the *Dryas* islands on scree, but lichens are less common — in frequency and cover as well as in species diversity.

TABLE 16. PHYSIOGNOMY OF *DRYAS* - GRAMINOID COMMUNITY

	% COVER POINTS	% QUADRAT FREQUENCY	PROMINENCE VALUE
Total Vascular Plants (31 spp.)	59	100	590.0
Dwarf Shrubs	20	100	200.0
Compact Forbs	6	96	58.8
Single-growing Forbs	11	100	110.0
Graminoids	30	100	300.0
Bryophytes (9 spp.)	18	95	172.5
Lichens (12 spp.)	2	85	18.4
Terricolous	1	75	8.7
Saxicolous	1	35	6.0
Open Gravel and Boulders	40	100	400.0

The prominence value of graminoidal species, with grasses predominating over the sedges, is about half that of all vascular plants. *Agropyron latiglume* and *Festuca brachyphylla* are the most important grasses and

Carex petricosa the most abundant sedge. Graminoids accounted for a very much smaller proportion of the *Dryas* island vegetation. In addition, the sedges in the *Dryas* - graminoid community were of much better vitality and species determination of the carices was facilitated by the presence of flowering spikelets which were generally absent in the scree community sedge plants.

The absence of *Selaginella densa* and the presence of *Salix arctica* in this community suggest a more moist environment than that of the scree areas. In addition, *Potentilla diversifolia* and *Artemisia norvegica*, both good indicators of more mesic conditions, are more common here. Another reflection of more mesic conditions is the greater prominence of forb species growing mostly singly over those with a compact growth form.

This is the only stand in which *Astragalus alpinus* and *Pedicularis flammea* were present, though neither was abundant. *Astragalus* was also present in other areas low on the S slope and on the W slope. The only other place that *Pedicularis flammea* was found was the farthest E slope of Signal Mountain.

Three of the nine mosses collected from the *Dryas* - graminoid community, *Abietinella abietina, Campylium polygamum,* and *Hypnum procerrimum*, were not collected from any other stand. *Tomenthypnum nitens* was found here and at moist or wet locations on the N slope.

TABLE 17. SPECIES STRUCTURE OF *DRYAS* - GRAMINOID COMMUNITY

SPECIES	% COVER SCALE	% COVER POINT	% QUADRAT FREQUENCY	PROMINENCE VALUE
VASCULAR PLANTS:				
Dwarf shrubs				
Dryas hookeriana	20.0	17.0	90	189.74
Salix nivalis	3.2	1.5	50	22.98
S. arctica	2.1	1.5	35	12.42
Forbs with compact growth form				
Silene acaulis	4.3	4.5	35	25.14
Oxytropis podocarpa	3.9	1.0	35	23.07
Potentilla nivea	1.0	0.5	60	7.75
Oxytropis campestris	0.8	1.0	15	2.90
Antennaria alpina	0.4		15	1.55
Astragalus alpinus	0.3	0.5	10	0.79
Saussurea densa	0.1	0.5	5	0.22
Crepis nana	0.03		5	0.07
Draba nivalis	0.03		5	0.07
Forbs growing mostly singly				
Polygonum viviparum	3.3	4.5	85	29.96
Potentilla diversifolia	2.4	1.5	55	17.80
Artemisia norvegica	2.4	3.0	35	14.20
Solidago multiradiata	1.7	1.5	40	11.07
Gentiana prostrata	0.9	1.0	65	7.26
Gentianella propinqua	0.8		45	5.37
Campanula uniflora	0.8	1.0	40	5.06
Arnica alpina	0.6		10	1.90
Myosotis alpestris	0.6		10	1.90
Campanula lasiocarpa	0.2		10	0.79
Stellaria monantha	0.2		10	0.79
Pedicularis flammea	0.2		10	0.79
Graminoids				
Agropyron latiglume	6.6	11.5	80	59.03
Festuca brachyphylla	6.0	5.5	80	53.67
Carex petricosa	4.6	6.0	75	39.84
Poa arctica	0.9		40	5.69
Carex scirpoidea	0.3	0.7	45	2.01
Poa alpina	0.4		15	1.55
Carex atrosquama	0.1		5	0.22

TABLE 17. Cont'd.

SPECIES	% COVER		% QUADRAT FREQUENCY	PROMINENCE VALUE
	SCALE	POINT		
BRYOPHYTES:				
Abietinella abietina				
Campylium polygamum				
Dicranum fuscescens				
Encalypta sp.				
Hypnum procerrimum				
H. revolutum				
Orthotrichum sp.				
Tomenthypnum nitens				
Tortella fragilis				
LICHENS:				
Caloplaca jungermanniae				
C. stillisideorum				
Cetraria cucullata	0.1	3.0	70	12.55
C. islandica	0.7		40	4.43
C. nivalis	0.5	1.0	50	5.30
C. tilesii	0.2		10	0.63
Cladonia pocillum	2.0	1.5	15	6.78
Cornicularia aculeata	0.5	1.0	30	4.11
Ochrolechia uppsaliensis				
Peltigera lepidophora				
Physcia muscigena	0.1		5	0.22
Thamnolia subuliformis	0.5	1.0	45	5.02

C. *DRYAS - KOBRESIA* COMMUNITY

Habitat Description

Uneven topography, with some sorted stone stripes and many boulders, is characteristic of the very dry SW slope of Signal Mountain (Plate 13), immediately below the West Summit (Fig. 3). The weathering arenaceous outcrop above the community studied is the probable source of many boulders. The stand representing this area (Stand #1) was located at an elevation of about 2225 m (7300 ft) and had a slope angle of 20°.

As this area receives the brunt of prevailing winds from the W and SW, it generally has no more than a thin cover of snow in winter. During the winter of 1968-69, which received a smaller than normal amount of snowfall, this area was observed (from the valley below) to have many snow-free patches.

The poor snow cover and consequent moisture deficits together with the windy and southerly exposure, have promoted an extremely chionophobous community. Since this area was visited only a few times, phenological observations were scant, but it appeared that peak anthesis occurred about the same time as at community B. Microenvironmental data were not, unfortunately, obtained at this site.

The area of the stand was 1394 m^2 (15,000 ft^2).

PLATE 13. *Dryas - Kobresia* community in an area of poor winter snow cover on the SW slope of Signal Mountain. Many boulders and uneven topography are characteristic of this dry slope. (Photographed July 5, 1967).

This is another community with very coarse, sandy loam soil containing a large number of rock fragments, including gravel, cobbles and large boulders (see Plate 13). The amount of non-vegetated ground, in the form of gravel and larger rock fragments in stone stripes, is much less here, however, than in the two previously discussed communities.

The very coarse materials in the soil profile may be due to the addition of some glacial drift deposits to fragments resulting from weathering processes. The deeper development of an Ah horizon in this profile suggests that the soil in this area is relatively more stable and thus has developed, *in situ*, over a longer period of time than that of the *Dryas* - graminoid community. Roots penetrated to a depth of 30 cm. The pH (6.5) was almost the highest of all the soils collected from Signal Mountain.

Vegetation

Since this was the first stand to be analyzed, techniques were still in the process of being formulated and perfected. Only the cover scale was used here and cover values were probably underestimated. Another point of difficulty arose from the short duration of the season. Vegetation sampling was carried out at this stand on July 5, at which time many species were not fully developed, hence lower cover values were obtained.

The *Dryas* - *Kobresia* community is also a *Dryas* -

graminoid type, but sedges are the dominant component here in contrast to community B where grasses dominate.

TABLE 18. PHYSIOGNOMY OF *DRYAS - KOBRESIA* COMMUNITY

	% COVER SCALE	% QUADRAT FREQUENCY	PROMINENCE VALUE
Total Vascular Plants (28 spp.)	50	100	500.0
Dwarf Shrubs	30*	100	300.0
Compact Forbs	3*	76	27.8
Single-growing Forbs	12*	67	13.3
Graminoids	2*	85	114.4
Bryophytes (11 spp.)	11	73	94.0
Lichens (13 spp.)	7	97	64.0
Terricolous	6	94	56.3
Saxicolous	1	3	1.9
Open Gravel and Boulders	13	52	91.9

* estimated from data

Species diversity was only slightly lower here than in community B, 50 species as compared with 52, but was almost average for the Signal Mountain communities.

The individual plants in this community exhibited about the poorest vitality of any in this study, probably a reflection of the high potential evapotranspiration and abrasional processes attributable to wind, both in winter and in summer. The dominant *Dryas hookeriana* was very closely appressed to the ground. Many dead cushions of *Silene acaulis* were noted, far outnumbering those that were living. As most of the dead cushions did not support other plants, as is often the case, it appeared that the rigorous

physical environment might account for the unusually high mortality.

Kobresia bellardii, a characteristic species of relatively snow-free alpine areas, is found on Signal Mountain at the western end and the ridge summit. *Carex scirpoidea* was also quite prominent in this community, as well as in other areas on the mountain where pikas had overwintered under the snow and had left an extensive carpet of droppings.

Forbs in this community were similar to those of community B but were far less prominent here. Additional species were *Pedicularis oederi*, the only site where it was found, and *Zygadenus elegans* which was uncommon here and found only occasionally at other sites low on the S slope.

The most common bryophytes are the mosses *Bryum stenotrichum, Dicranum fuscescens* and *Tortella fragilis*. Two mosses and a liverwort, *Drepanocladus uncinatus, Hylocomium splendens* and *Barbilophozia hatcheri* were found in a depression adjacent to the lee and shady side of a large boulder where they grew abundantly. This is the only community from which the moss *Myurella julacea* was collected.

Lichen cover, especially terricolous species, was higher here than in communities A and B. The most prominent of these were *Cladonia pocillum, Cetraria nivalis* and *C. cucullata*.

TABLE 19. Cont'd.

SPECIES	% COVER (SCALE)	% QUADRAT FREQUENCY	PROMINENCE VALUE
BRYOPHYTES:			
Bryum stenotrichum			
Dicranum fuscescens			
Distichium capillaceum			
Drepanocladus uncinatus			
Encalypta sp.			
Hylocomium splendens			
Myurella julacea			
Rhytidium rugosum			
Tortella fragilis			
LICHENS:			
Alectoria ochroleuca	0.2	10	0.63
Cetraria cucullata	1.5	73	12.82
C. islandica	0.9	39	5.62
C. nivalis	2.0	79	17.78
C. tilesii	0.2	10	0.63
Cladonia pocillum	4.1	52	29.42
Cladonia sp.	0.4	36	2.40
Cornicularia aculeata	0.5	30	2.47
Ochrolechia uppsaliensis			
Peltigera canina var. *rufescens*	0.05	10	0.14
Physcia muscigena			
Rhizocarpon geographicum			
Solorina bispora			
Thamnolia subuliformis	1.1	48	7.66

* T = Trace.

Footnote: In addition to the mosses listed above, a liverwort, *Barbilophozia hatcheri*, was also present.

TABLE 19. SPECIES STRUCTURE OF *DRYAS - KOBRESIA* COMMUNITY

SPECIES	% COVER (SCALE)	%QUADRAT FREQUENCY	PROMINENCE VALUE
VASCULAR PLANTS:			
Krummholz			
Picea engelmannii	T*	0	
Dwarf shrubs			
Dryas hookeriana	28.0	79	248.87
Salix nivalis	3.5	55	25.84
Salix arctica	0.3	3	0.52
Forbs with compact growth form			
Selaginella densa	1.4	42	8.75
Potentilla nivea	0.9	42	6.09
Silene acaulis - living	0.6	9	1.80
- dead	2.0	18	8.25
Antennaria alpina	0.3	9	0.90
Oxytropis campestris	0.2	6	0.49
Ranunculus gelidus	0.02	3	0.03
Oxytropis podocarpa	0.02	3	0.03
Forbs growing mostly singly			
Polygonum viviparum	0.6	39	3.75
Solidago multiradiata	0.5	24	2.45
Gentiana prostrata	0.4	27	2.08
Potentilla diversifolia	0.2	15	0.78
Artemisia norvegica	0.2	12	0.69
Stellaria monantha	0.2	12	0.69
Campanula uniflora	0.2	9	0.60
Pedicularis oederi	0.2	6	0.49
Arnica alpina	0.1	6	0.25
Campanula lasiocarpa	0.1	6	0.25
Hedysarum alpinum	T	0	
Myosotis alpestris	T	0	
Zygadenus elegans	T	0	
Graminoids			
Kobresia bellardii	11.3	73	96.55
Carex scirpoidea	1.9	52	13.63
Trisetum spicatum	1.9	48	13.31
Poa arctica	0.4	15	1.55
Poa alpina	0.02	3	0.03

D. *DRYAS* - LICHEN COMMUNITY ON THE RIDGE SUMMIT

Habitat Description

The summit of the main ridge of Signal Mountain is a fellfield of rock outcrops and boulders, presenting a diversity of contrasting microhabitats. In places where the inorganic material is fine enough, congeliturbation is common during seasons with frequent crossings of the freezing point, thereby keeping small patches of gravel and soil free of vegetation.

Since the ridge is exposed to much wind, snow cannot accumulate to any great depth, except in depressions and on the lee side of boulders and outcrops. Because of its exposure, the ridge is released from snow fairly early in the season. The peak number of species in anthesis occurred during the first two weeks in July in 1967.

The microenvironmental station (ME-4) at the summit of Signal showed this to be a location of intermediate temperatures, with maxima lower than at stations on the S slope and higher than those on the N slope. Minimum temperatures were also intermediate, again being higher than those of N slope stations.

The area chosen for quantitative sampling (Stand #6) is near the western end of the mountain (see Fig. 2), at an elevation of 2255m (7397 ft). This portion of the ridge trends in an ENE to WSW direction.

PLATE 14. An oblique view of the *Dryas* - lichen community on the rocky ridge of Signal Mountain. The summit (elev. 2266 m) is in the centre background, with Mount Tekarra (elev. 2688 m) in the distance to the right.

(Photographed July 27, 1967).

The size of the sampled area was 2787 m^2 (30,000 ft^2), making this the largest stand that was analyzed.

Because of the large amount of outcropping bedrock, soil depth was very variable and mostly very shallow. The pit that was dug to collect soil samples was in a location where a deeper than average profile had accumulated. It is therefore representative, probably, of maximum rather than average soil development on the ridge. The profile consisted of an Ah horizon capping the C horizon with little evidence of development of the B. The upper soil was a loam whereas the lower was a sandy loam. This profile was much less coarse than those of communities A, B and C. Roots were found extending to a depth of only 17 cm, which was shallower than at the first three communities discussed. The soil was found to be strongly acid throughout the profile.

Vegetation

With 70 species counted in this community, species diversity here was the highest of the communities studied, not only as the total but also within the vascular and lichen groups. The diversity of species is no doubt due largely to the diversity of microhabitats, as indicated by the presence of typical south slope species such as *Oxytropis podocarpa* and *Anemone drummondii*, and typical north slope species such as *Pedicularis lanata* (Table 21). This is reflected in the position of this community in the vegetation gradient diagram (Fig. 14) where it is surrounded by communities A, B, C and E.

The highest Index of Similarity is with the *Dryas - Kobresia* (C) community (73.7, Table 13).

TABLE 20. PHYSIOGNOMY OF *DRYAS* - LICHEN COMMUNITY

	% COVER POINTS	% QUADRAT FREQUENCY	PROMINENCE VALUE
Total Vascular Plants (35 spp.)	65	97	646.8
Dwarf Shrubs	39	97	388.1
Compact Forbs	12	80	119.8
Single-growing Forbs	4	77	35.1
Graminoids	10	90	94.9
Bryophytes (11 spp.)	13	90	123.5
Lichens (24 spp.)	26	100	260.0
Terricolous	20	97	198.6
Saxicolous	6	40	38.0
Open Gravel and Soil	12	43	78.7
Rock Outcrops and Boulders	12	33	68.9

The compact growth forms (mats, cushions, tufts and rosettes) are by far the most common in this community and the dominant and most prominent vascular species are all in this group (Table 21). Single-growing species are the least prominent group. As in the *Dryas - Kobresia* community, the Cyperaceae are more important here than are the Gramineae.

Silene acaulis achieves its highest prominence in this ridge top habitat. Although some dead cushions of *Silene* were found, the proportion was much smaller than in community C; evidence of successful invasion by other species, e.g., *Kobresia bellardii* and *Polygonum viviparum*, were noted. *Saxifraga oppositifolia* and *Draba incerta* were not found in any other analyzed community but were in rock crevice areas.

TABLE 21. SPECIES STRUCTURE OF *DRYAS* - LICHEN COMMUNITY

SPECIES	% COVER SCALE	% COVER POINT	% QUADRAT FREQUENCY	PROMINENCE VALUE
VASCULAR PLANTS:				
Dwarf shrubs				
Dryas hookeriana	25.0	27.0	90	246.66
Salix nivalis	6.0	11.0	90	85.38
Salix arctica	0.6	0.7	13	2.52
Vaccinium vitis-idaea	0.5	0.7	10	1.90
Cassiope tetragona	T*		0	
Forbs with compact growth form				
Selaginella densa	2.0	4.0	50	21.21
Silene acaulis - living	3.2	4.0	27	19.75
- dead	1.9	1.3	10	5.06
Oxytropis podocarpa	3.0	2.0	40	16.44
Saxifraga oppositifolia	0.8	1.3	10	3.48
Potentilla nivea	0.7	0.3	30	2.74
Antennaria alpina	0.3		17	1.24
Anemone drummondii	0.1		3	0.17
Arenaria sajanensis	0.04		13	0.14
Draba nivalis	0.01		3	0.01
Arenaria rossii	T		0	
Draba incerta	T		0	
Oxytropis campestris	T		0	
Forbs growing mostly singly				
Campanula lasiocarpa	0.9	1.3	53	8.01
Polygonum viviparum	0.7		43	4.59
Campanula uniflora	0.4	1.0	20	3.58
Pedicularis lanata	0.4		17	1.65
Stellaria monantha	0.2	0.3	27	1.56
Artemisia norvegica	0.3	0.7	3	0.87
Myosotis alpestris	0.3	0.3	3	0.52
Potentilla diversifolia	0.1	0.3	3	0.35
Saxifraga cernua	0.1		7	0.26
Arnica alpina	0.1		3	0.17
Gentiana prostrata	0.002		3	0.01
Gentianella propinqua	T		0	
Graminoids				
Kobresia bellardii	3.7	4.0	30	21.36
Carex spp.	0.8	2.0	53	10.92
Agropyron latiglume	1.2		13	4.33
Poa arctica	0.6		13	2.16
Festuca baffinensis	0.3	4.0	13	1.08
Poa alpina	0.1		3	0.17
Other grass spp.	0.3		37	1.82

TABLE 21. Cont'd.

SPECIES	% COVER SCALE	% COVER POINT	% QUADRAT FREQUENCY	PROMINENCE VALUE
BRYOPHYTES:				
Liverwort				
Barbilophozia hatcheri				
Mosses				
Aulacomnium turgidum				
Bryoerythrophyllum recurvirostre				
Dicranum fuscescens				
Encalypta rhaptocarpa				
Hypnum revolutum				
Orthotrichum sp.				
Pohlia nutans				
Polytrichum juniperinum				
Rhytidium rugosum				
Tortella fragilis				
LICHENS:				
Alectoria ochroleuca	0.1		20	0.45
A. tenuis				
A. vexillifera				
Caloplace jungermanniae				
Candelariella aurella				
Cetraria cucullata	1.3	5.0	83	28.70
C. islandica	1.0	1.0	63	7.94
C. nivalis	0.9	1.3	87	10.26
C. tilesii	0.5	0.3	53	2.91
Cladonia pyxidata	1.1	1.3	37	7.30
Cladonia sp.				
Cornicularia aculeata	0.4	0.3	33	2.01
Dactylina arctica	0.02		3	0.03
Hypogymnia intestiniformis				
Lecanora epibryon				
L. verrucosa				
Omphalodiscus kraschenninnikovii				
Parmelia sulcata				
Peltigera sp.	0.3	0.7	13	1.80
Rhizocarpon geographicum				
Rinodina turfacea				
Solorina octospora				
Stereocaulon alpinum	0.2	1.0	13	2.16
Thamnolia subuliformis	0.7	2.7	80	15.21

* T = Trace.

Lichens have a high species diversity (24), and their total prominence is equal to that of *Dryas hookeriana*. They are also well dispersed, occurring in all quadrats. All the lichens present in the south slope communities are also present on the ridge, and generally in greater abundance than in the former areas. *Dactylina arctica*, which normally grows only in moist habitats on the north slope, was found in a depression on the ridge, as were *Cassiope tetragona* and the liverwort *Barbilophozia hatcheri*.

The most common mosses are *Dicranum fuscescens*, *Rhytidium rugosum* and *Tortella fragilis*. The two latter species are typical of relatively dry habitats and all three were found in community C. Two typically north slope mosses, *Aulacomnium turgidum* and *Pohlia nutans*, were collected from the *Dryas* - lichen community also. This is the only location where *Bryoerythrophyllum recurvirostre* was found.

E. *DRYAS* - MOSS COMMUNITY

Habitat Description

Hummocky solifluction microterraces, often with open gravelly tops, and scattered boulders are features of this most extensive community type of the N slope, of which Stand #2 is representative.

PLATE 15. *Dryas* - moss community in an area of earliest snow release on the N slope. The lighter green areas are dominated by *Dryas hookeriana*; the dark green tufts are *Cassiope tetragona*.

In the distance, across the Maligne River valley, is the Colin Range.

(Photographed July 11, 1967).

Stand #2 has a due N aspect and an overall slope angle of 7°. Because it is near the W end of Signal Mountain it receives more wind than other portions of the N slope. The topography is somewhat convex, due, probably, to more resistant underlying arenaceous rock. These topographic factors in combination make this community the first on the N slope to be released from snow. Thus, although snowpatches well above persisted into August, extensive areas covered by this community type, even in more easterly locations, were already free of snow on the first exploratory trip of June 4, 1967. The high vegetational similarity (I_{sim} = 72) with the ridge top community is therefore understandable.

The microenvironmental station (ME-6) near this site recorded soil temperatures that were lower than those of the summit and the S slope but higher than all others on the N slope. However, both maximum and minimum air temperatures were lower here than those of all but the station at the very wet site.

The elevation of the stand is 2195 m (7200 ft). The sampled area was 929 m^2 (10,000 ft^2) in size.

Soil samples were obtained from a pit that was dug at the base of a microterrace and the profile therefore probably represents the best soil development under this vegetation type. The Ah horizon was a loam while the CA and C horizons were gravelly sandy loams with cobbles and stones

increasing with depth. Although the soils are finer in texture than the soils already discussed (communities A to D) they are about average for N slope soils. Because of the relatively finer texture the available moisture values are higher, also, than in the previous communities. This area probably has better drained soils than most N slope areas.

Although this is considered the most xerophytic community of the north slope, soil moisture would be adequate most years because of the presence of melting snowbanks above. Only after several weeks of very warm, dry weather, such as was experienced in late July and August in 1967 when all the snowpatches disappeared, does the moisture reach very low levels.

Vegetation

Species diversity in this community is 55, about average for Signal Mountain (Table 22). Both vascular plants and bryophytes have a higher cover here than in the S slope and ridge top communities, but lichen cover is lower.

A striking difference in the *Dryas* - moss community of the N slope as compared with the communities of the S slope and ridge top is that the prominence of compact forbs is greatly reduced and that of the single-growing species is increased (Table 22).

TABLE 22. PHYSIOGNOMY OF *DRYAS* - MOSS COMMUNITY

	% COVER SCALE	% QUADRAT FREQUENCY	PROMINENCE VALUE
Total Vascular Plants (29 spp.)	58	100	580.0
Dwarf Shrubs	53*	100	530.0
Compact Forbs	2*	71	16.9
Single-growing Forbs	6*	100	60.0
Graminoids	4*	96	38.1
Bryophytes (12 spp.)	20	100	200.0
Lichens (14 spp.)	5	100	50.0
Open Gravel and Rock	10	46	68.0

* estimated from data

Dryas hookeriana and *Arnica alpina* achieve here their highest prominence values of all the communities analyzed. The *Salix nivalis* value was exceeded only in the ridge top community (D). *Salix arctica* is more prominent here than in any of the previously discussed communities.

Cassiope tetragona commonly occurs in small depressions and its importance therefore varies with the amount of slightly depressed microtopography that is present (Plate 15). *Silene acaulis* is the most important of the herbaceous compact growth form group and here also, as in the ridge top community, it is being invaded successfully by other species.

TABLE 23. SPECIES STRUCTURE OF *DRYAS* - MOSS COMMUNITY

SPECIES	% COVER (SCALE)	% QUADRAT FREQUENCY	PROMINENCE VALUE
VASCULAR PLANTS:			
Dwarf shrubs			
Dryas hookeriana	29.5	92	282.95
Salix nivalis	5.5	86	51.00
S. arctica	2.7	58	20.56
Cassiope tetragona	2.9	21	13.29
Vaccinium vitis-idaea	0.6	17	2.47
Forbs with compact growth form			
Silene acaulis - living	2.0	29	12.12
- dead	0.4	4	0.80
Antennaria alpina	1.2	46	8.14
Selaginella densa	0.2	4	0.40
Draba crassifolia	0.1	4	0.20
Arenaria sajanensis	0.02	8	0.06
Potentilla nivea	T*	4	0.01
Oxytropis podocarpa	T	0	
Forbs growing mostly singly			
Polygonum viviparum	2.1	75	18.19
Pedicularis capitata	1.4	42	9.07
Campanula lasiocarpa	1.2	50	8.49
Arnica alpina	0.7	17	2.89
Potentilla hyparctica	0.5	21	2.29
P. diversifolia	0.4	17	1.65
Gentiana prostrata	0.3	17	1.24
Campanula uniflora	0.3	13	1.06
Pedicularis lanata	0.2	8	0.57
Artemisia norvegica	0.2	4	0.40
Solidago multiradiata	0.1	4	0.20
Graminoids			
Carex drummondiana	2.1	83	19.13
C. petricosa	1.5	58	11.42
Poa arctica	0.4	17	1.65
Festuca baffinensis	0.3	8	0.85
Hierochloe alpina	0.1	4	0.20
Luzula spicata	0.1	4	0.20

TABLE 23. Cont'd.

SPECIES	% COVER (SCALE)	% QUADRAT FREQUENCY	PROMINENCE VALUE
BRYOPHYTES:			
Aulacomnium turgidum			
Brachythecium turgidum			
Bryum pseudotriquetrum			
Dicranum fuscescens			
Ditrichium flexicaule			
Distichium capillaceum			
Hylocomium splendens			
Hypnum revolutum			
Meesia uliginosa			
Pogonatum alpinum			
Rhacomitrium canescens			
Rhytidium rugosum			
LICHENS:			
Alectoria nitidula			
A. ochroleuca			
Cetraria cucullata	0.4	58	3.06
C. ericetorum	0.2	33	1.15
C. islandica	0.2	17	0.84
C. nivalis	0.3	58	2.29
Cladonia mitis	0.2	29	1.08
C. pocillum	0.7	33	4.05
Dactylina arctica	0.02	4	0.04
Ochrolechia uppsaliensis			
Peltigera aphthosa			
Solorina octospora			
Stereocaulon alpinum	0.1	22	0.47
Thamnolia subuliformis	0.3	45	2.02

* T = Trace.

The mosses in this community are chiefly N slope species, but the two most common species are *Ditrichum flexicaule* which was collected only from this stand, and *Dicranum fuscescens* which was collected from all but the very wet community.

Cetraria tilesii, a common lichen in all the S slope and the ridge top communities, is conspicuously absent from this and all other N slope communities.

The *Dryas* - moss community is a highly variable type. The stand that was studied is likely the most xerophytic of this type because of its location toward the W end of the mountain. In more mesophytic phases of this community, *Dryas hookeriana* and mosses remain dominant but *Salix arctica* and moss cover increase with an increase in moisture supply from snowmelt seepage. The compact forb species disappear with added moisture, as do *Gentiana prostrata, Campanula uniflora* and *Festuca baffinensis.* This disappearance may be related, at least in some of the species, not so much to the additional moisture itself as to additional competition resulting from the additional moisture.

F. *CASSIOPE TETRAGONA - DRYAS* COMMUNITY

Habitat Description

The *Cassiope tetragona - Dryas hookeriana* community is another very common community type on the N slope. Only very small patches are found on the S slope. Stands of this community type occur in slightly depressed and/or protected areas and therefore can accumulate considerable amounts of snow.

Snow release is later than in areas covered by the *Dryas* - moss community. On June 4, 1967, the edges of two snowpatches were marked out with flags. Upon return to these areas two weeks later, the flags were found marking the outer edges of *Cassiope tetragona* tussock areas. Peak anthesis was reached about the second week in July that year. No temperature or wind data were obtained from this community type.

The microtopography is very uneven due to the tussocks of *Cassiope* and hummocks caused by an adequate amount of soil moisture from snowmelt and consequent frost heaving (Plate 16). The representative community, Stand #3, had a NNW slope aspect, an angle of 13°, and an elevation of 2228 m (7310 ft). The sampled area was 1394 m^2 (15,000 ft^2).

Fragments ranging from gravel to boulders are notably scarce on the surface and in the upper portion of the soil

profile. The loam to sandy loam soil is weakly differentiated into horizons and becomes gravelly in the C horizon. Roots penetrate to 21 cm, which is not as deep as in the *Dryas* - moss community although the soil texture is comparatively coarser in the latter.

Vegetation

Species diversity was lower than average, with a total of 44 species (Table 24), although the *Cassiope tetragona* - *Dryas* community is more mesophytic than the previous communities discussed and has a greater vegetation cover, particularly of vascular plants. Bryophyte species diversity in this stand (7) is the lowest of all communities analyzed. The bryophytes here are all N slope or constant alpine species, and all were relatively common in the stand.

TABLE 24. PHYSIOGNOMY OF *CASSIOPE TETRAGONA - DRYAS* COMMUNITY

	% COVER SCALE	% QUADRAT FREQUENCY	PROMINENCE VALUE
Total Vascular Plants (25 spp.)	79	100	790.0
Dwarf Shrubs	79*	100	790.0
Compact Forbs	2*	40	12.3
Single-growing Forbs	8*	92	76.6
Graminoids	3*	50	21.1
Bryophytes (7 spp.)	7	100	70.0
Lichens (12 spp.)	10	96	97.9
Open Gravel and Rock	T**	0	

* estimated from data

** T = trace.

PLATE 16. *Cassiope tetragona* - *Dryas hookeriana* community on the N slope of Signal Mountain, showing the dark green tussocks of *Cassiope* and the lighter green *Dryas* between them. The higher area beyond supports a *Dryas* - moss community.

The Colin Range is in the distance, with Sirdar Mountain, the highest peak in the range, at the left.

(Photographed July 14, 1969).

TABLE 25. SPECIES STRUCTURE OF *CASSIOPE TETRAGONA - DRYAS* COMMUNITY

SPECIES	% COVER (SCALE)	% QUADRAT FREQUENCY	PROMINENCE VALUE
VASCULAR PLANTS:			
Krummholz			
Picea engelmannii	T*	0	
Dwarf shrubs			
Cassiope tetragona	41.0	96	403.73
Dryas hookeriana	18.7	80	168.59
Salix nivalis	4.7	71	39.60
S. arctica	3.2	56	23.95
Vaccinium vitis-idaea	0.2	8	0.57
Phyllodoce glanduliflora	T	0	
Forbs with compact growth form			
Gentiana glauca	1.3	32	7.07
Antennaria alpina (?monocephala)	0.6	20	2.68
Silene acaulis	0.6	4	1.20
Arenaria sajanensis	0.1	4	0.20
Lycopodium selago	T	0	
Forbs growing mostly singly			
Campanula lasiocarpa	2.2	60	17.04
Artemisia norvegica	2.4	48	16.63
Polygonum viviparum	1.7	36	10.20
Pedicularis lanata	0.6	16	2.40
P. capitata	0.2	4	0.40
Stellaria monantha	0.1	4	0.20
Graminoids			
Carex drummondiana	0.8	20	3.59
Poa alpina	0.6	16	2.40
Carex nigricans	0.6	12	2.08
Luzula arcuata	0.4	8	1.13
Carex sp.	0.2	4	0.40
Poa arctica	0.1	4	0.20
Trisetum spicatum	0.1	4	0.20
BRYOPHYTES:			
Liverwort			
Barbilophozia hatcheri			

TABLE 25. Cont'd.

SPECIES	% COVER (SCALE)	% QUADRAT FREQUENCY	PROMINENCE VALUE
Mosses			
Dicranum fuscescens			
Drepanocladus uncinatus			
Hylocomium splendens			
Pogonatum alpinum			
Pohlia cruda			
Polytrichum piliferum			
LICHENS:			
Cetraria cucullata	0.4	12	1.39
C. ericetorum	2.6	71	21.84
C. nivalis	0.4	16	1.60
Cladonia gracilis			
C. gracilis chordalis			
C. mitis	2.4	79	21.36
C. pocillum			
C. pyxidata			
Dactylina arctica	1.5	38	9.23
Nephroma expallidum			
Peltigera aphthosa	0.4	12	1.39
P. aphthosa leucophlebia			
Stereocaulon alpinum	0.4	12	1.39
Thamnolia subuliformis	0.1	4	0.20

*T = Trace.

Dwarf shrubs have a higher species diversity and are far more prominent here than in any other community except the *Cassiope mertensiana - Phyllodoce glanduliflora* community (J). Single-growing species are also comparatively important, particularly *Campanula lasiocarpa, Artemisia norvegica* and *Polygonum viviparum*, all of which are present in the more xerophytic S slope communities as well as in most of those on the N slope. No species are present in this community exclusively, although *Gentiana glauca* was found in only one other community. This is the first community described in which *Carex nigricans* was found.

Lichens are fairly abundant, with *Cetraria ericetorum* and *Cladonia species* the most common.

G. *DRYAS - EMPETRUM - SALIX ARCTICA* COMMUNITY

Habitat Description

Many small solifluction terraces, or terracettes ("pancake terraces"), occurring close together to produce a garland pattern, form the characteristic topography of the *Dryas hookeriana - Empetrum nigrum* community, which is restricted to the N slope. Although the area was dry in July, sufficient water for mass slumpage into terracettes is obviously present at some time, probably early in the season when snowmelt is rapid. Some sorting by water and frost has taken place and areas of bare gravel, up to 2 m across, give one the impression of small "pancakes" strewn

on the mountainside when viewed from above, hence the name "pancake terraces". These gravel areas form a fairly level terracette top (Plate 17). Some boulders are also present.

This community is floristically distinct from the others due to the presence and abundance of *Empetrum*, but it is much less common than the other N slope communities studied. Although the representative stand (Stand #11) was located toward the eastern end of the mountain, this community type was found in more westerly locations as well. Stand #11 had an overall NE aspect and was located at an elevation of 2220 m (7280 ft). This area is generally flat, with a slope angle of 6°, when compared with the steep slope above. The individual terracettes range from 20 to 30 cm in height and their slope angles from 25° to 55°. A decrease in slope angle appeared to be correlated with an increase in the height of the terracettes.

A soil pit was dug under each of the three types of cover: one in the open gravel area (#11G), one under *Dryas* cover (#11D), and one under an *Empetrum* mat (#11E). The two profiles under vegetation were similar but the one under gravel was very different. The latter had a thin surface layer of gravel and cobbles overlying yellow loam with many cobbles and stones, occasional roots between 2 and 20 cm in depth, and pH of 5.4, which is slightly higher than in the other two. Some gleying had occurred under vegetation causing the soils of these profiles to be dark grey in colour

with occasional reddish streaks in the B horizon under *Dryas*. Roots extended to 28 cm in both profiles.

Soils under *Dryas* are clay loam in the Ah horizon and clay in the B. Under *Empetrum* the Ah is clay and the B is gravelly clay. Compared to soils from other communities soils from these two pits (#11D and #11E) had the highest clay content. Because the soil under *Empetrum*, on riser portions of the terracettes, is coarser than that under *Dryas*, between the terracettes, water retention and available moisture values are correspondingly higher under *Dryas*.

The sampled area was 930 m^2 (10,000 ft^2) in size.

Vegetation

The diversity of the microtopography has produced, in effect, microcommunities of plants within the community type.

TABLE 26. PHYSIOGNOMY OF *DRYAS - EMPETRUM* COMMUNITY

	% COVER POINTS	% QUADRAT FREQUENCY	PROMINENCE VALUE
Total Vascular Plants (28 spp.)	67	100	670.0
Dwarf Shrubs	60	90	569.8
Compact Forbs	1	20	4.5
Single-growing Forbs	8	90	73.9
Graminoids	5	90	47.5
Bryophytes (16 spp.)	29	95	282.6
Lichens (14 spp.)	15	100	150.0
Open Gravel and Boulders	25	75	217.0

PLATE 17. The *Dryas - Empetrum - Salix arctica* community on garland terracettes on the N slope of Signal Mountain. The small terraces average 25 cm in height and are topped with bare gravel. *Empetrum nigrum* covers the riser portion and is associated with *Cassiope tetragona* and *Phyllodoce* species at the base. *Dryas hookeriana* dominates in the area between the terracettes. (North is toward the lower left corner of the photograph.)

(Photographed June 24, 1967).

The total species diversity here (58) is the highest of the north slope communities, but is exceeded by those of the scree and the ridge top. Bryophyte diversity is the highest in this and the very wet areas, both with 16 species.

Empetrum nigrum is dominant on the terracette risers and bases where some shade is provided during part of the day by the small solifluction lobes. The lobes are oriented toward the N and NE. Areas between terracettes are dominated by *Dryas hookeriana*, and since these areas are larger *Dryas* has the greatest prominence in this community (Plate 17).

Salix arctica is more prominent here than in the previous communities discussed. *Vaccinium vitis-idaea* has a greater prominence value here than in any other community. Both these dwarf shrubs and *Salix nivalis* are present chiefly in the *Dryas* dominated portions of this community. The other ericaceous shrubs, however, are chiefly associated with *Empetrum* at the bases of the terracettes.

Most of the single-growing species, notably *Artemisia norvegica*, *Campanula lasiocarpa* and *Polygonum viviparum*, are found in the *Dryas* dominated areas. The more compact, closed cover of *Empetrum* probably inhibits the establishment of the single-growing species.

Although the shrubby mat-forming group is important, the forb mat-cushion-rosette group is low in number of species, in frequency and in cover (Table 27).

TABLE 27. SPECIES STRUCTURE OF *DRYAS - EMPETRUM* COMMUNITY

SPECIES	% COVER SCALE	% COVER POINT	% QUADRAT FREQUENCY	PROMINENCE VALUE
VASCULAR PLANTS:				
Dwarf Shrubs				
Dryas hookeriana	20.5	29.5	85	230.48
Empetrum nigrum	18.5	20.5	45	130.81
Salix arctica	9.0	8.5	85	81.13
Vaccinium vitis-idaea	6.3	6.5	85	59.00
Phyllodoce empetriformis	1.0	1.5	10	4.11
Phyllodoce glanduliflora	1.0	1.5	10	4.11
Salix nivalis	1.5	0.5	10	3.16
Cassiope tetragona	0.1	0.5	5	1.68
Forbs with compact growth form				
Antennaria alpina	0.4		20	1.79
Arenaria sajanensis	0.1		10	0.02
Gentiana glauca	*T		0	
Lycopodium selago	T		0	
Silene acaulis	T		0	
Forbs growing mostly singly				
Artemisia norvegica	2.6	6.0	50	30.41
Polygonum viviparum	1.9	2.0	65	12.90
Campanula lasiocarpa	0.6	0.5	40	3.48
Potentilla hyparctica	0.1		5	0.22
Stellaria calycantha	0.03		5	0.06
Solidago multiradiata	T		0	
Graminoids				
Calamagrostis inexpansa	4.2	3.0	60	27.88
Luzula spicata	0.7	0.5	30	3.29
Carex scirpiformis	0.4		20	1.79
Festuca brachyphylla	0.3		25	1.50
Carex petricosa	0.1	0.5	5	0.67
Poa arctica	0.1		5	0.22
Trisetum spicatum	0.1		5	0.22
Juncus biglumis	0.03		5	0.06
Poa alpina	0.03		5	0.06
BRYOPHYTES:				
Liverworts				
Barbilophozia hatcheri				
Gymnomitrium varians				
Ptilidium pulcherrimum				

TABLE 27. Cont'd.

SPECIES	% COVER SCALE	% COVER POINT	% QUADRAT FREQUENCY	PROMINENCE VALUE
Mosses				
Aulacomnium palustre				
A. turgidum				
Bryum creberrimum				
B. pseudotriquetrum				
Dicranum fuscescens				
Grimmia apocarpa				
Grimmia sp.				
Hylocomium splendens				
Paraleucobryum enerve				
Rhacomitrium lanuginosum				
Rhytidium rugosum				
Tortella tortuosa				
LICHENS:				
Alectoria ochroleuca				
Cetraria cucullata	1.4	3.5	80	22.36
C. islandica	0.5	1.0	20	3.35
C. nivalis	1.8	3.0	75	20.78
Cladonia mitis *C. pocillum*	2.2	2.0	70	17.57
Cornicularia aculeata	0.4	0.5	30	2.41
Dactylina arctica	1.2	1.0	40	6.96
Nephroma expallidum				
Peltigera canina var. *rufescens* *P. malacea*	2.1	2.0	15	7.94
Stereocaulon alpinum	1.9	2.0	30	10.68
Thamnolia subuliformis	1.0	2.0	70	12.55
Umbilicaria hyperborea	1.1		10	3.48

*T = Trace.

The graminoid diversity (9) is the highest of all the communities. *Calamagrostis inexpansa*, which is a prominent grass in this community, was not found in any other stand.

The most common bryophytes included a liverwort, *Barbilophozia hatcheri*, and five mosses: *Dicranum fuscescens*, *Hylocomium splendens*, *Hypnum revolutum*, *Aulacomnium turgidum*, and *Rhacomitrium lanuginosum*.

H. *DRYAS - SALIX ARCTICA* COMMUNITY

Habitat Description

Solifluction is a common process in regions with cold climates and occurs in both arctic and alpine areas (Andersson 1906). Although permafrost is generally the base on which the downslope creep or slumping takes place in the arctic, the base is chiefly bedrock in alpine areas such as on Signal Mountain.

Solifluction terraces are very common features of the N slope of Signal (Plate 18). The riser portion is usually at least 1 m high (Plate 19) and may be up to 3 m high where water and unconsolidated materials are more abundant (Plate 20). The advancing solifluction lobe is often convex in outline and in profile. The most active solifluction on Signal Mountain undoubtedly took place during the past. However, there is evidence that some solifluction is still occurring, particularly during the alpine spring when

snowmelt runoff is copious. Some of the terraces have overhanging turf, and plants near the bases are being buried.

A microenvironmental station (ME-7) was located on the riser of a low solifluction terrace which had a rather gentle slope. Air temperatures here had the greatest range of all the stations, but the mean was similar to that of others on the N slope except the very wet area. Soil temperatures were the second highest of the four N slope stations, probably because the steeper slope of the riser contributes to well drained soil.

No sorting of materials was evident in the terraces that were examined, with both coarse and fine particles appearing to have moved *en masse*. Soil pits were dug at the top of one terrace and at the bases of two terraces, but not through riser areas.

Two terraces, each 1 m or higher in places, were analyzed. The vegetation data following is the average of the two stands (#5A and #8A). The combined area was about 27 m^2. The terraces are located at elevations of 2160 and 2165 m (7090 and 7105 ft, respectively). As solifluction does not proceed evenly the terrace lobes have aspects ranging from NNE to NNW.

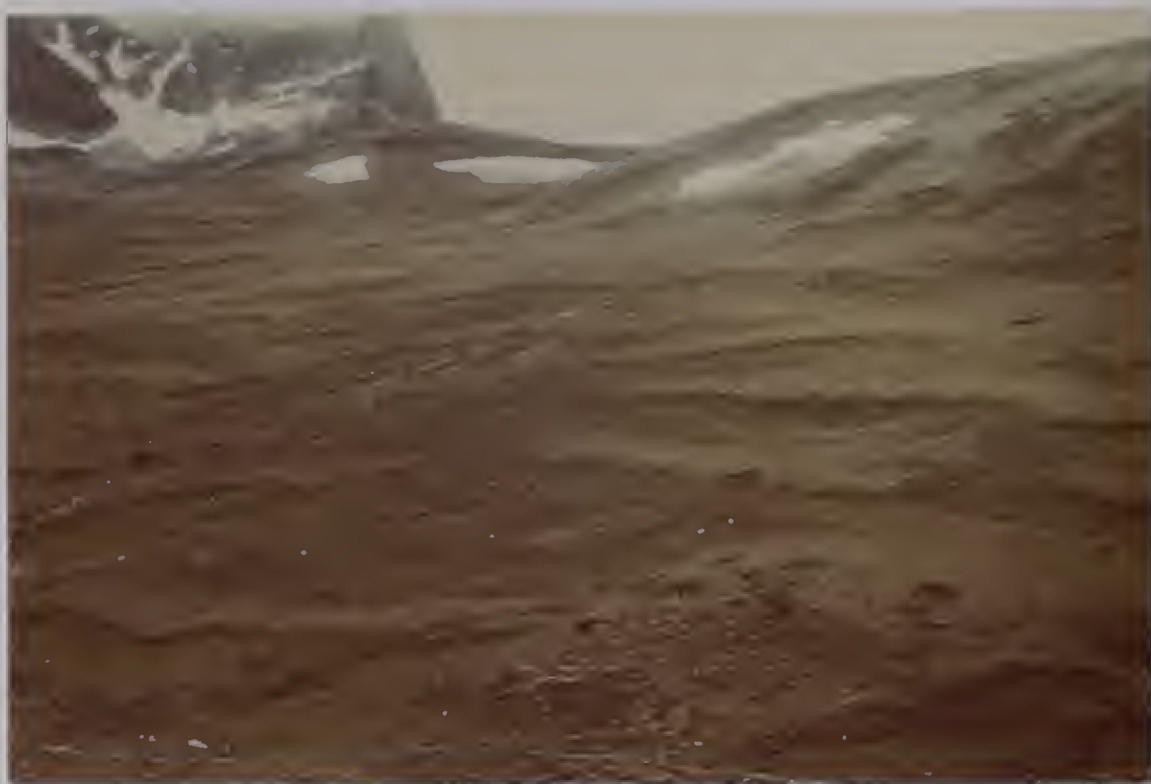


PLATE 18. The N slope of Signal Mountain showing extensive development of solifluction terraces. Late-lying snowpatches supply meltwater to the slopes below throughout most of the summer. The central patch of snow on Signal, located at the right of the "East Knob", is the snowbank glacier shown on Plate 23 (p. 160).

The line near the bottom of the aerial photograph is the Skyline Trail to Maligne Lake. Mt. Tekarra is at the upper left.

(Photographed August 21, 1968).

PLATE 19. A smaller solifluction terrace, about 1 m high, on the N slope of Signal Mountain (Stand #5). The terrace top is dominated by *Dryas hookeriana* (in full bloom on July 19, 1967, when photographed) and mosses. The terrace riser is covered by a *Dryas* - *Salix arctica* community (H), and the 2 m wide base by a *Cassiope mertensiana* - *Phyllodoce glanduliflora* community (J). The yellow flowers in the foreground are those of *Phyllodoce* in a transitional area with *Antennaria lanata*. The brownish patches in the background are late snowpatch areas dominated by *Carex nigricans* (community M).

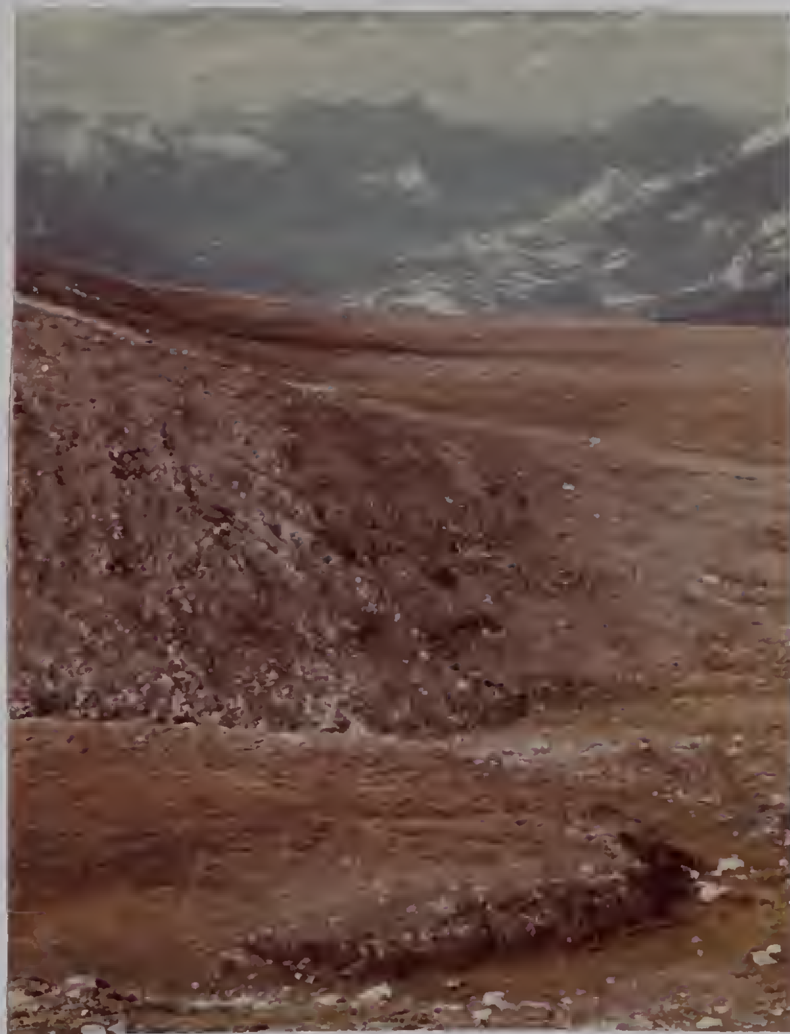


PLATE 20. Large solifluction lobe, almost 3 m high, below an area of late snowmelt on the N slope of Signal Mountain. The top of the terrace and the area immediately below it are very wet throughout the summer due to a continual supply of meltwater from a snowbank glacier (out of the photograph above and to the left; see Plate 23).

The view is toward the NNW, with the Athabasca River valley in the distance.

(Photographed September 4, 1967).

Vegetation

The *Dryas - Salix arctica* community has the smallest range in its Indices of Similarity with other communities, if the *Carex nigricans* community (M) is disregarded, ranging from 30 to 46%. Both dominant species are common in other communities and there are no species that are exclusive to this community type.

The total species diversity (52) is average for Signal Mountain. The low lichen diversity (6) is likely related to the physical instability of the terrace and perhaps at least partly to the shading of this stratum by the topographic relief and the taller vascular plants.

TABEL 28. PHYSIOGNOMY OF *DRYAS - SALIX ARCTICA* COMMUNITY

	% COVER POINTS*	% QUADRAT FREQUENCY**	PROMINENCE VALUE
Total Vascular Plants (31 spp.)	66	100	664.0
Dwarf Shrubs	37	100	370.0
Compact Forbs	6	81	54.0
Single-growing Forbs	42	100	420.0
Graminoids	10	70	84.0
Bryophytes (15 spp.)	13	88	125.3
Lichens (6 spp.)	6	81	54.0

* from Stand #8A

** from Stands #5A and #8A

Single-growing species are far more prominent (Table 28) than in any of the previously discussed communities.

TABLE 29. SPECIES STRUCTURE OF *DRYAS - SALIX ARCTICA* COMMUNITY

SPECIES	% COVER*	% QUADRAT FREQUENCY	PROMINENCE VALUE
VASCULAR PLANTS:			
Dwarf shrubs			
Dryas hookeriana	15.0	75	129.90
Salix arctica	7.8	100	78.00
Cassiope tetragona	2.5	25	12.50
Phyllodoce glanduliflora	T	0	
Forbs with compact growth form			
Sibbaldia procumbens	0.7	19	3.05
Silene acaulis	0.8	13	2.85
Arenaria sajanensis	0.3	13	1.06
Antennaria lanata	0.2	4	0.39
Forbs growing mostly singly			
Artemisia norvegica	6.0	63	47.43
Erigeron peregrinus	4.8	81	43.20
Solidago multiradiata	6.5	31	36.40
Senecio triangularis	6.5	28	34.45
Campanula lasiocarpa	3.0	100	30.00
Arnica latifolia	4.0	25	20.00
Polygonum viviparum	2.5	44	16.58
Gentiana prostrata	2.5	38	15.31
Potentilla diversifolia	1.8	56	13.10
Ranunculus eschscholtzii	1.3	63	10.28
Anemone parvifolora	1.9	25	9.50
Veronica alpina	1.4	44	9.29
Pyrola secunda	1.3	13	4.60
Castilleja occidentalis	0.9	19	4.10
Trollius albiflorus	0.8	13	2.83
Gentianella propinqua	0.1	19	0.44
Pedicularis capitata	0.2	4	0.39
Botrychium simplex	T	4	0.01
Stellaria monantha	T	4	0.01
Pedicularis bracteosa	T	0	
Caltha leptosepala	T	0	
Graminoids			
Carex spectabilis	4.1	50	28.71
Poa arctica	0.5	19	2.05
Deschampsia caespitosa	0.3	6	0.73
Grass sp.	0.2	4	0.39
Carex scirpoidea	0.04	13	0.14

TABLE 29. Cont'd.

SPECIES	% COVER	% QUADRAT FREQUENCY	PROMINENCE VALUE
BRYOPHYTES:			
Liverworts			
Preissia quadrata	0.2	3	0.34
Barbilophozia hatcheri	0.3	6	0.73
Mosses			
Aulacomnium palustre			
Brachythecium salebrosum			
Dicranum bonjeanii			
D. fuscescens			
Ditrichum flexicaule			
Drepanocladus uncinatus			
Hylocomium splendens			
Mnium orthorrhynchum			
Pogonatum alpinum			
Pohlia cruda			
Tomenthypnum nitens			
Tortella tortuosa			
Tortula norvegica			
LICHENS:			
Cetraria islandica	0.3	13	1.06
Cladonia cariosa			
C. chlorophaea	0.4	31	2.12
C. pocillum			
Peltigera canina var. *rufescens*	1.4	38	8.57
Stereocaulon alpinum	0.006	6	0.01

*% Cover based on data from two stands; including scale and point methods from #8A and scale only from #5A.

Although *Dryas hookeriana* and *Salix arctica* are the dominant species, the large-leaved Compositae - *Arnica latifolia, Artemisia norvegica, Erigeron peregrinus, Senecio triangularis* and *Solidago multiradiata* - taken together are nearly as abundant as the dominants (Table 29). Perhaps this single growth form has an important adaptive value in the relatively unstable environment of a solifluction terrace riser.

Dryas, Silene acaulis and *Stellaria monantha* are not present in the communities that follow. The riser habitat, therefore, probably represents the most mesic in the tolerance ranges of these species.

As a result of the more mesic and more protected conditions prevailing here, over 40% of the vascular flora are species not found in the previously discussed communities. These are: *Sibbaldia procumbens, Antennaria lanata, Erigeron peregrinus, Arnica latifolia, Ranunculus eschscholtzii, Anemone parviflora, Veronica alpina, Pyrola secunda, Castilleja occidentalis, Trollius albiflorus, Carex spectabilis* and *Deschampsia caespitosa.* All these are present in one or more communities whose descriptions are following.

Campanula lasiocarpa, which is present in all but the *Carex nigricans* community, achieves its highest prominence value in the terrace riser community. *Abies lasiocarpa* krummholz is often found rooted on risers of terraces in the

lower alpine zone. Two species, the grape-fern *Botrychium simplex* and the thallose liverwort *Preissia quadrata*, are rare on terrace risers and were not found in any other community.

The most abundant mosses are *Brachythecium salebrosum*, *Pohlia cruda* and *Dicranum fuscescens*. The leafy liverwort *Barbilophozia hatcheri* forms extensive mats in the more shaded areas in which mosses are rather rare. Whether the virtual exclusion of mosses in areas of thick carpets of *Barbilophozia* is due to competition or to other ecological factors is not known.

The two terrace risers that were analyzed were similar to each other in floristic composition because environmental conditions were similar. On risers of terraces that are wetter, and solifluction is presumably more active, the species composition is different (e.g.,Plate 20). Although not analyzed, the major difference noted was the lack of *Dryas hookeriana* and its associates, and an increase in graminoids in both number of species and cover.

J. *CASSIOPE MERTENSIANA - PHYLLODOCE GLANDULIFLORA* COMMUNITY

Habitat Description

The base areas of solifluction terraces accumulate large amounts of snow that is retained several weeks longer than on the tops of the terraces and on the risers. Because the slope angle is relatively smaller than that of the risers

snowmelt runoff is less rapid at the base than it is in the riser portions of terraces. Also, because terraces have greater accumulations of soil and rock fragments than do the base areas, the water table is closer to the surface in the latter. The consequent favourable moisture balance throughout most of, if not all, summer contributes to the lush vegetation cover (Plate 21) and to better developed soils (see Plate 8).

The two areas that were analyzed (Stands #5B and #8B) occupy strips of rather uneven ground extending 2 m out from the terraces. The total area was 54 m^2, the slope angle 10° to 15°, the aspect NNE to NNW, and the elevations 2160 to 2165 m.

The soil profiles showed a pronounced development of the Ah horizon, with the lower horizons somewhat more weakly developed. Texturally, the soils are fine loams to sandy loams, becoming gravelly below 20 cm depth. There is some evidence of gleization and both mottling and iron nodules are present. Roots extend down to 33 cm.

Vegetation

Vascular species diversity is relatively high compared with other Signal Mountain communities; bryophyte diversity is average; but lichen diversity (as well as cover) is very low (Table 30).

The prominence of both single-growing and graminoid

PLATE 21. Patterned ground on the N slope of Signal Mountain, seen from the air. The prominent bright green bands are at the bases of solifluction terraces, the tops of the terraces are yellowish green, and the narrow shadowed areas are the terrace risers.

Fast-flowing meltwaters from snowbanks above are responsible for the gravel pattern at the right. Less pronounced patterns below the terrace bases are probably due to meltwaters flowing down more slowly from snow that accumulates at and protects the bases. Infiltration of some meltwater contributes to solifluction processes.

The approximate scale of the photograph is 1 cm = 3 m.

(Photographed August 21, 1968).

species is higher at the terrace base than in any of the previously described communities. Although the dominants are different, more than half the species growing at the terrace base are also present in the riser community, including the prominent *Artemisia norvegica, Arnica latifolia, Erigeron peregrinus* and *Potentilla diversifolia*. *Trollius albiflorus* is much more common in the terrace base community than on the riser.

TABLE 30. PHYSIOGNOMY OF *CASSIOPE MERTENSIANA - PHYLLODOCE GLANDULIFLORA* COMMUNITY

	% COVER POINTS*	% QUADRAT FREQUENCY **	PROMINENCE VALUE
Total Vascular Plants (33 spp.)	95	100	950.0
Dwarf Shrubs	66	100	660.0
Compact Forbs	5	91	47.8
Single-growing Forbs	29	91	276.7
Graminoids	33	100	330.0
Bryophytes (11 spp.)	52	96	509.6
Liverworts	16	50	112.2
Mosses	36	96	352.8
Lichens (3 spp.)	2	36	12.0
Exposed Rock	1	5	2.2

* data from Stand #8B only

** data from Stands #5B and #8B

There is often a good demonstration of niche partition by *Cassiope tetragona* and *C. mertensiana* at solifluction terraces. The more mesophytic and highly chionophilous *C. mertensiana* is found at the bases of terraces and sometimes on the lower portions of risers, particularly the more

shallow risers. *C. tetragona* is comparatively more xerophytic and only moderately chionophilous, thus it is present on the upper portions of risers and in slight depressions on the terrace tops. The two species sometimes overlap a little but never completely.

Salix arctica is not nearly so prominent as *Cassiope mertensiana* and *Phyllodoce glanduliflora*, but is still the fourth most abundant species. *Carex spectabilis* is third in quantitative importance and was only found at the terrace base and in smaller amount in the riser community. The terrace base community is the only one in which the common subalpine species, *Vaccinium scoparium*, was found.

Phyllodoce empetriformis, which is often associated with *P. glanduliflora*, was not present here. The ecological requirements of the two, as with the *Cassiope* species, are probably somewhat different.

Antennaria lanata is fairly prominent (Table 31), particularly toward the outside of the base area, which is the lowermost portion.

A moss, *Brachythecium salebrosum*, and a liverwort, *Barbilophozia hatcheri*, are the most common bryophytes present in this community. Both are also important in the terrace riser community.

TABLE 31. SPECIES STRUCTURE OF *CASSIOPE MERTENSIANA* - *PHYLLODOCE GLANDULIFORA* COMMUNITY

SPECIES	% COVER*	% QUADRAT FREQUENCY	PROMINENCE VALUE
VASCULAR PLANTS:			
Dwarf shrubs			
Cassiope mertensiana	25.9	96	249.19
Phyllodoce glandulifora	19.2	50	135.76
Salix arctica	5.9	91	56.28
Vaccinium scoparium	0.7	18	2.99
Salix nivalis	0.4	9	1.20
Forbs with compact growth form			
Antennaria lanata	3.4	64	27.20
Sibbaldia procumbens	1.2	23	5.72
Ranunculus eschscholtzii	0.5	41	2.95
Forbs growing mostly singly			
Artemisia norvegica	6.0	73	51.16
Arnica latifolia	7.7	36	46.45
Trollius albiflorus	3.0	46	20.24
Erigeron peregrinus	2.1	68	17.34
Potentilla diversifolia	1.7	50	12.02
Epilobium alpinum	3.8	9	11.46
Pyrola secunda	2.6	18	11.09
Veronica alpina	1.2	64	9.60
Polygonum viviparum	1.1	55	7.75
Pedicularis capitata	1.1	41	7.30
Campanula lasiocarpa	0.9	36	5.40
Senecio triangularis	1.0	9	3.00
Anemone parviflora	0.6	23	2.86
Senecio parviflorus	0.3	14	1.11
Stellaria calycantha	0.2	5	0.42
Castilleja spp.	T	0	
Pedicularis bracteosa	T	0	
Graminoids			
Carex spectabilis	6.4	86	59.49
C. scirpoidea	2.0	23	9.29
Phleum alpinum	1.0	5	2.12
Deschampsia caespitosa	0.3	5	0.64
Poa epilis	0.2	5	0.42
Deschampsia atropurpurea	0.04	5	0.08
Other grass spp.	0.8	18	3.41
Luzula wahlenbergii	T	0	
Juncus drummondii	T	0	

TABLE 31. Cont'd.

SPECIES	% COVER	% QUADRAT FREQUENCY	PROMINENCE VALUE
BRYOPHYTES:			
Liverwort			
Barbilophozia hatcheri	12.8	50	90.51
Mosses			
Brachythecium salebrosum			
Bryum pseudotriquetrum			
Dicranum bonjeanii			
Drepanocladus uncinatus			
Hylocomium splendens			
Pogonatum alpinum			
Pohlia cruda			
Tortula norvegica			
LICHENS:			
Cetraria islandica	0.05	9	0.15
Peltigera aphthosa var. *leucophlebia*			
Cladonia sp.			

*% Cover represents mean values of data from stands #8B (scale and point methods) and #5B (scale only).

K. *SALIX ARCTICA - ARCTAGROSTIS* - MOSS COMMUNITY

Habitat Description

Although there are several areas on the N slope that are very wet early in the season when the snowmelt rate is high, only one remained very wet throughout the entire summer of 1967. The *Salix arctica - Arctagrostis arundinacea* - moss community is at this location (Plate 22). It is situated below the saddle (see Figs. 2, 3) and to the NE of it, at an elevation of about 2227 m (7300 ft). It is also below and due N of the snowbank glacier, the only one on Signal Mountain (Plate 23), which supplies meltwater throughout the summer.

Meltwater reaches this site (Stand #12) via a seepage spring immediately beyond the base of the large solifluction lobe (see Plate 20). The slope angle is small (4°) but enough for a slow, continual downward movement of much of the water. The water was tested and gave a neutral reaction.

A considerable amount of congeliturbation has occurred in this very wet area. Stone nets consisting of fairly large boulders have formed, particularly at the lower portion of the stand (at left in Plate 22). Many hummocks are present and a soil pit was dug in one of these.

Moss cover is high and the soil is peaty. The top 7 cm of the hummock profile was undecomposed moss remains, chiefly *Sphagnum*, within which many vascular plants were rooted.

PLATE 22. The *Salix arctica - Arctagrostis arundinacea* - moss community in a very wet area on the N slope of Signal Mountain. The white object is a styrofoam shelter on a thermometer (ME-8).

In the middle distance is a N shoulder of Mt. Tekarra. Colin Range is in the far distance.

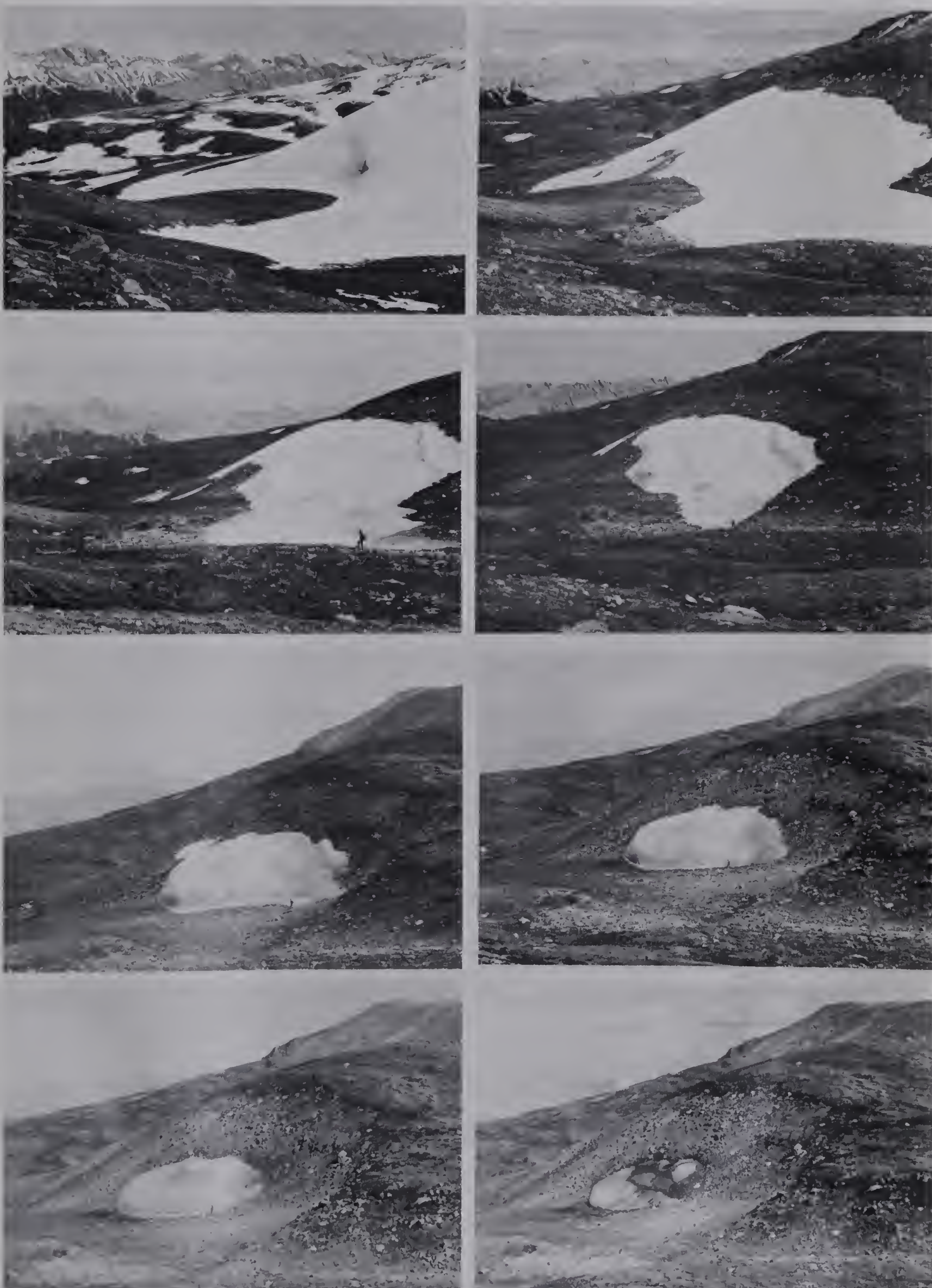
(Photographed August 16, 1967).

PLATE 23. Melting stages of the Signal Mountain snowbank glacier in 1967.

From left to right and top to bottom:

(1) June 4	(2) July 1
(3) July 12	(4) July 25
(5) August 10	(6) August 18
(7) August 25	(8) September 5

The elevation of the base of the ice in (8) is about 2255 m (7395 ft).



There was no mineral soil until 10 cm depth, with much glei and mottling. Roots extend to a depth of 40 cm.

The mineral soil was fine in texture, heavy clay to clay loam, with no gravel, cobbles nor stones until 44 cm depth, where large rocks were present. In areas within the stand where water is moving and there is little or no rooted vegetation, the substrate under the water is very gravelly and stony.

Although the soil reaction was medium to strongly acid, the pH values (5.8 and 5.4) are average or higher than the average for Signal Mountain soils. Perhaps the pH values would be lower here were it not for the washing action of moving water. The water retention and available water values were the highest of all the soil samples collected from Signal, due to the presence of absorptive mosses such as *Sphagnum*.

The microenvironmental station at this site consistently recorded the lowest air and soil temperatures of all the stations.

The sampled area was about 915 m^2 (3000 ft^2) in size, and plots included water-covered and hummocky areas.

Vegetation

Vascular species diversity (24) in this very wet area is the second lowest for Signal Mountain communities, but the bryophyte diversity is the highest. The latter, chiefly

mosses, have much higher cover and prominence values here than in any other community. Lichen diversity, cover and frequency are all low, but not as low as in the terrace base community (J). The graminoid element is more prominent here than are the other phanerogamic growth forms (Table 32).

TABLE 32. PHYSIOGNOMY OF *SALIX ARCTICA - ARCTAGROSTIS -* MOSS COMMUNITY

	% COVER POINTS	% QUADRAT FREQUENCY	PROMINENCE VALUE
Total Vascular Plants (24 spp.)	70	100	700.0
Dwarf Shrubs	23	100	230.0
Compact Forbs	16	83	145.9
Single-growing Forbs	24	91	229.4
Graminoids	36	100	360.0
Bryophytes (16 spp.)	85	100	850.0
Lichens (6 spp.)	7	16	28.0
Non-vegetated	24	33	138.0
Exposed Rock	4	25	20.0
Open Water	20	25	100.0

Several vascular species present in this community were not found in any of the others that were analyzed: *Equisetum scirpoides*, *Petasites frigidus*, *Cerastium beeringianum*, *Cardamine bellidifolia*, *Salix alaxensis*, and all the graminoids except *Deschampsia caespitosa*, which achieved its highest prominence here, *Poa arctica* and *Phleum alpinum*.

Salix arctica was the only vascular species that was present in all quadrats, on hummocks and in wetter situations. *Equisetum*, *Cardamine*, *Salix alaxensis*, *Arctagrostis*,

Deschampsia caespitosa, Carex phaeocephala, Juncus castaneus and *Eriophorum* are all characteristic of wet areas. *Cerastium beeringianum, Artemisia norvegica, Campanula lasiocarpa, Potentilla diversifolia, P. hyparctica, Veronica alpina, Gentiana prostrata, Poa arctica* and all the lichens were found only on hummocks. The presence of the supposedly less mesophytic *Cassiope tetragona* rather than *C. mertensiana* was unexpected. This might be related to snow duration, but unfortunately the snow release date for this site was not noted.

Half the bryophytes at this site were not found in any other sampled communities, but most of them were found in and along a small streamlet toward the western end of the N slope from which a bryophyte collection was made (Plate 24). These hydrophilic species are *Orthocaulis floerkii, Brachythecium turgidum, Calliergon giganteum, C. sarmentosum, Campylium stellatum, Drepanocladus vernicosus, Philonotis fontana* and *Sphagnum warnstorfianum.*

All the mosses and liverworts in Table 33 are abundant and most of them very much intertwined with each other. The most common are *Drepanocladus vernicosus*, which grows in and is moved by the full current of the flowing water; and *Tomenthypnum nitens, Hylocomium splendens* and *Sphagnum warnstorfianum* which are quite firmly attached to the ground, forming cushions and hummocks.

TABLE 33. SPECIES STRUCTURE OF *SALIX ARCTICA* - *ARCTAGROSTIS* COMMUNITY

SPECIES	% COVER SCALE	% COVER POINT	% QUADRAT FREQUENCY	PROMINENCE VALUE
VASCULAR PLANTS:				
Dwarf shrubs				
Salix arctica	9.6	21.7	100	157.00
Cassiope tetragona	0.8		9	2.40
Salix alaxensis	T*		0	
Forbs with compact growth form				
Equisetum scirpoides	6.0	11.7	75	94.96
Cerastium beeringianum	0.04	0.8	8	1.13
Cardamine bellidifolia	0.04		8	0.11
Forbs growing mostly singly				
Artemisia norvegica	9.4	11.7	42	68.70
Petasites frigidus	5.2	5.8	42	35.64
Polygonum viviparum	2.3	4.2	67	27.01
Campanula lasiocarpa	0.3	4.2	42	14.26
Ranunculus eschscholtzii	1.8	0.8	58	9.90
Potentilla diversifolia	1.3	2.5	25	9.50
Veronica alpina	1.3	0.8	42	6.80
Potentilla hyparctica	0.2		8	0.57
Gentiana prostrata	T		0	
Saxifraga aestivalis	T		0	
Graminoids				
Arctagrostis arundinacea	15.6	20.8	67	148.97
Carex phaeocephala	4.7	10.0	58	60.16
Deschampsia caespitosa	5.2	6.6	42	38.24
Juncus castaneus	1.3	1.7	25	7.50
Eriophorum scheuchzeri	1.4		8	4.05
Agrostis variabilis	0.2		8	0.57
Poa arctica	0.2		8	0.57
Phleum alpinum	T		0	
BRYOPHYTES:				
Liverworts				
Barbilophozia hatcheri				
Orthocaulis floerkii				

TABLE 33. Cont'd.

SPECIES	% COVER SCALE	% COVER POINT	% QUADRAT FREQUENCY	PROMINENCE VALUE
Mosses				
Aulacomnium palustre				
Brachythecium turgidum				
Bryum pseudotriquetrum				
Calliergon giganteum				
C. sarmentosum				
Campylium stellatum				
Distichium capillaceum				
Drepanocladus vernicosus				
Hylocomium splendens				
Philonotis fontana				
Pogonatum alpinum				
Polytrichum juniperinum				
Sphagnum warnstorfianum				
Tomenthypnum nitens				
LICHENS:				
Cladonia arbuscula ssp. *berengeriana*	0.8		9	2.40
C. pocillum				
Cetraria cucullata	0.2	0.8	9	1.50
C. nivalis	0.04		9	0.12
Peltigera aphthosa	0.2		9	0.60
P. aphthosa var. *leucophlebia*				

*T = Trace.

PLATE 24. A streamlet on the N slope of Signal Mountain whose bed supports a lush growth of bryophytes, including the liverwort *Orthocaulis floerkii*, and the mosses *Bryum pseudotriquetrum, Calliergon sarmentosum, Dicranum fuscescens, Distichium capillaceum, Drepanocladus uncinatus, D. vernicosus, Grimmia alpicola, Hylocomium splendens,* and *Tomenthypnum nitens*.

The vegetation on the banks is dominated by *Dryas hookeriana* together with mostly different moss species (community E).

(Photographed August 12, 1967).

L. *SALIX ARCTICA - ANTENNARIA LANATA* COMMUNITY

Habitat Description

The chionophilous *Salix arctica - Antennaria lanata* community is relatively common on Signal Mountain and is generally found in fairly high snow accumulation areas, i.e., slight depressions or bordering deeper ones. Although much more prevalent on the N, it occasionally occurs on the S slope near depressions holding very late snowpatches.

Snow depth and duration are usually greater here than in any of the previously described communities. Moisture availability is probably high, particularly during the early part of the growing season when snowmelt waters from above tend to irrigate slightly depressed areas more than steeper slopes.

The analyzed community (Stand #9, Plate 25) was located on the N slope and was 465 m^2 (5000 ft^2) in area. The microtopography is uneven due to the presence of many boulders and hummocks. The aspect is due N, the slope angle about 10°, and the elevation about 2160 m (7090 ft).

Two soil pits were dug at this site: one in a relatively flat area and the other in an average-sized hummock, 15 cm high and 45 cm in diameter. The soil depth in the two was very similar, but the profiles were not.

The profile in the latter area has a thick Ah horizon,

PLATE 25. *Salix arctica - Antennaria lanata* community on the N slope of Signal Mountain. The prominent yellow flowers are those of *Castilleja occidentalis*, at peak anthesis when photographed on August 11, 1967. The showy mauve flowers are those of *Erigeron peregrinus*.

about 17 cm deep. Texturally the top 20 cm is a fine loam but below that depth it becomes a very coarse gravelly loam. Root penetration is to 28 cm.

The hummock soil is very fine throughout, silty loam to loam, with an unusual profile. The Ah horizon here is only 6 cm thick and has the lowest soil reaction (pH 4.5) of all Signal Mountain soils. The effects of congeliturbation were obvious between 10 and 26 cm depth, with black lenses - presumably buried portions of the Ah horizon - interdigitating with more abundant ferruginous lenses and mottles from the B horizon, all in a yellow-brown matrix. Roots penetrate to 33 cm. The lower part of the hummock profile was very wet in 1968.

No microenvironmental data were obtained from this community type.

Vegetation

The *Salix arctica - Antennaria lanata* community is fairly distinct floristically from the others. The highest Index of Similarity is 38.5% with the terrace riser (H) and the very wet (K) communities (see Table 13).

Total species diversity (56) is almost the highest of north slope communities, being exceeded only by the *Dryas - Empetrum* community (G) of garland terracettes. Vascular species diversity (Table 35) is equal to that of the *Dryas -* lichen community (D) of the ridge top, and thus the highest

found in any community on Signal Mountain. All vascular growth forms have high frequency values, but graminoids have much lower cover than the others. Species with a single growth form are more prominent only in the terrace riser *Dryas - Salix arctica* community (H).

TABLE 34. PHYSIOGNOMY OF *SALIX ARCTICA - ANTENNARIA LANATA* COMMUNITY.

	% COVER POINTS	% QUADRAT FREQUENCY	PROMINENCE VALUE
Total Vascular Plants (36 spp.)	81	100	810.0
Dwarf Shrubs	38	100	380.0
Compact Forbs	26	100	260.0
Single-growing Forbs	29	100	290.0
Graminoids	13	90	119.6
Bryophytes (10 spp.)	46	100	460.0
Liverwort	5	30	27.4
Mosses	43	100	430.0
Lichens (9 spp.)	34	100	340.0
Terricolous	34	100	340.0
Saxicolous	1	5	2.2
Open Rocks	2	20	9.0

The vegetation has a very lush appearance and several vascular species achieve maximum prominence values in the *Salix arctica - Antennaria lanata* community. These include the two dominants, four other N slope species - *Sibbaldia procumbens*, *Erigeron peregrinus*, *Castilleja occidentalis*, *Pedicularis lanata* - and two constant species: *Artemisia norvegica* and *Polygonum viviparum*. Another constant species, *Campanula lasiocarpa*, is nearly as prominent here as in the

terrace riser community (H) where its maximum prominence occurred.

Erigeron peregrinus and *Castilleja occidentalis* were aspect dominants at the time of vegetation analysis. Because they were at the peak of anthesis and therefore very showy they appeared to be more prominent (Plate 25) and were deemed co-dominants with *Antennaria lanata*; final analysis proved otherwise (Table 35).

Both *Cassiope* species are present, with *C. mertensiana* much more prominent than *C. tetragona*. Other vascular species of fairly high prominence are *Veronica alpina, Luzula wahlenbergii* and *Carex drummondii:* the first two species were more prominent only in the *Carex nigricans* community (M). This is the only community in which *Carex microglochin* and *Lycopodium alpinum* were recorded. *Salix nivalis* was present but not common.

Both bryophytes and lichens are prominent. Lichens have a far greater prominence value here than in any other community. They are chiefly foliose (*Peltigera* species) and fruticose forms (*Stereocaulon alpinum, Cetraria,* and some *Cladonia* species).

The most abundant bryophytes are *Barbilophozia hatcheri, Drepanocladus uncinatus, Brachythecium salebrosum, Tortula norvegica* and *Dicranum fuscescens.*

TABLE 35. SPECIES STRUCTURE OF *SALIX ARCTICA - ANTENNARIA LANATA* COMMUNITY

SPECIES	% COVER SCALE	% COVER POINT	% QUADRAT FREQUENCY	PROMINENCE VALUE
VASCULAR PLANTS				
Dwarf Shrubs				
Salix arctica	21.0	25.0	100	230.00
Cassiope mertensiana	7.0	9.0	25	40.00
Cassiope tetragona	1.6	4.0	20	12.52
Salix nivalis	1.0	2.0	20	6.71
Phyllodoce glanduliflora	T*			
P. empetrifolmis	T			
Forbs with compact growth form				
Antennaria lanata	16.0	18.0	100	170.00
Sibbaldia procumbens	5.5	4.0	90	45.54
Arenaria sajanensis	1.3		45	8.72
Ranunculus eschscholtzii	1.2	1.0	55	8.16
Lycopodium alpinum	3.2	4.0	5	8.05
Gentiana glauca	0.8		15	3.10
Draba crassifolia	T		5	0.0002
Forbs growing mostly singly				
Artemisia norvegica	8.3	10.0	70	76.97
Erigeron peregrinus	4.8	5.0	85	45.18
Polygonum viviparum	3.6	5.0	50	30.41
Veronica alpina	3.5	3.0	80	29.52
Campanula lasiocarpa	3.4	3.0	80	28.62
Castilleja occidentalis	3.5	3.0	65	26.61
Hieracium gracile	2.2	0.5	40	8.85
Pedicularis lanata	1.5	1.5	30	8.22
Potentilla diversifolia	0.8	2.0	30	7.67
Arnica latifolia	0.3		10	0.95
Epilobium alpinum	0.1		5	0.22
Pyrola virens	0.1		5	0.22
Pedicularis bracteosa	T		0	
Lycopodium selago	T		0	
Graminoids				
Carex drummondiana	2.3	3.0	40	20.24
Luzula wahlenbergii	1.6	3.0	40	14.55
Carex microglochin	1.2	3.0	30	11.50
Poa epilis	1.0	2.0	30	8.22
Deschampsia atropurpurea	1.4	1.0	40	7.59
Poa alpina	0.8	0.5	15	2.71
Juncus drummondii	0.5	0.5	25	2.50
Carex nigricans	0.6	0.5	10	1.90
Grass sp.	0.5	0.5	5	1.12

TABLE 35. Cont'd.

SPECIES	% COVER		% QUADRAT	PROMINENCE
	SCALE	POINT	FREQUENCY	VALUE
BRYOPHYTES:				
Liverwort				
Barbilophozia hatcheri	2.4	4.5	30	17.90
Mosses				
Brachythecium salebrosum				
Bryum sp.				
Dicranum fuscescens				
Drepanocladus uncinatus				
Pogonatum alpinum				
Polytrichum juniperinum				
P. norvegicum				
P. piliferum				
Tortula norvegica				
LICHENS:				
Cetraria ericetorum	1.9		45	12.75
C. islandica				
Cladonia cariosa				
C. pocillum	6.3	12.5	60	58.13
C. pyxidata				
Lobaria linita				
Peltigera aphthosa	0.5	1.0	5	1.69
P. canina				
P. malacea	11.3	12.0	90	16.20

* T = Trace

Vegetation of the hummocks was very similar to that of the flatter portions of the microtopography.

The *Salix arctica - Antennaria lanata* vegetation observed on the S slope was lower in species diversity than was Stand #9. However, three additional species were found at the former site: *Agoseris aurantiaca, Arabis drummondii* and *Claytonia lanceolata*.

M. *CAREX NIGRICANS* COMMUNITY

Habitat Description

The *Carex nigricans* meadow is a common and distinctive constituent of the N slope vegetation mosaic, though relatively small in total area. This extremely chionophilous community type occupies areas of the latest snow release where a continuous cover of vegetation exists.

The *Carex nigricans* community is not restricted to the N slope although it is much more abundant there than elsewhere on Signal Mountain. On slopes of other aspects it is found in depressions deep and/or sheltered enough to accumulate snow of sufficient depth to be retained until July. Observations were made at two such depressions on the S slope; one of these is described later.

The analyzed representative of this community (Stand #10, Plate 26) is located on the N slope at an elevation of 2180 m (7150 ft), has a due N aspect and a slope angle of 17°.

PLATE 26. An extremely chionophilous *Carex nigricans* community on the N slope of Signal Mountain.

The area immediately below the boulder field is occupied by a *Salix arctica* - *Antennaria lanata* community, with transitional vegetation in the boulder field.

(Photographed August 13, 1967).

The stand was roughly triangular, with the apex upslope and an area of about 28 m^2 (300 ft^2). Because of the relatively small sampling area, data were obtained from 12 quadrats rather than the customary 20.

Some exposed rocks and many hummocks are present. All the hummocks appeared to be rocks over which vegetation and soil form a cover to a depth varying from 1 to 8 cm. No hummocks appeared to be caused by heaving of soil, as in the *Salix arctica - Antennaria lanata* community, although there was evidence of frost action in the soil profile between the rock hummocks. The *Carex nigricans* stand was located above the *Salix arctica - Antennaria lanata* stand (#9) and a boulder field with transitional vegetation covered a distance of 35 m between the two stands.

The comparatively deep (41 cm) solum in an area between hummocks consisted of a thin (3 cm) dark brown loam Ah horizon, overlying 30 cm of brown silty loam with some black and much ferruginous mottling, the mottling increasing somewhat with depth. The soil below 33 cm was a brownish yellow silty loam with a considerable amount of gravel and cobbles. Roots penetrate to 35 cm.

There are no micrometeorological data for this community type.

Vegetation

The *Carex nigricans* community is vegetationally the most

distinct of the analyzed communities of Signal Mountain; its highest Index of Similarity, with the *Salix arctica - Antennaria lanata* community (L), is only 8.7% and the mean Index with all communities only 1.1. It is also species - poor, having not only the lowest total species diversity (30) but the lowest diversity in each of the plant groups (Table 36). In addition, it is the only community in which the graminoid growth form is the most prominent and the mat-cushion-tufted dwarf shrubs and forbs have the lowest prominence values.

TABLE 36. PHYSIOGNOMY OF *CAREX NIGRICANS* COMMUNITY

	% COVER POINTS	% QUADRAT FREQUENCY	PROMINENCE VALUE
Total Vascular Plants (20 spp.)	100	100	1,000.0
Dwarf Shrubs	2	17	8.4
Compact Forbs	7	75	60.8
Single-growing Forbs	10	91	95.1
Graminoids	98	100	980.0
Bryophytes (8 spp.)	19	100	190.0
Liverworts	1	17	4.1
Mosses	18	100	180.0
Lichens (2 spp.)	1	17	4.1
Exposed Rock	4	17	16.7

Carex nigricans forms a rather dense mat and achieves here the highest prominence value recorded for any species in any of the communities analyzed. The second most abundant species is *Luzula wahlenbergii*. Both these species are uncommon in or absent from the other community types.

TABLE 37. SPECIES STRUCTURE OF *CAREX NIGRICANS* COMMUNITY

SPECIES	% COVER SCALE	% COVER POINT	% QUADRAT FREQUENCY	PROMINENCE VALUE
VASCULAR PLANTS:				
Dwarf shrubs				
Salix arctica	0.9	1.8	9	4.20
Vaccinium vitis-idaea	0.2	0.8	9	1.50
Forbs with compact growth form				
Ranunculus eschscholtzii	4.0	4.2	75	35.51
Sibbaldia procumbens	2.1	2.5	25	11.50
Antennaria lanata	0.2		9	0.60
Forbs growing mostly singly				
Veronica alpina	4.0	4.2	83	37.35
Epilobium alpinum	2.0	2.5	58	17.52
Arnica latifolia	1.9	1.8	25	9.50
Hieracium gracile	1.3	0.8	25	5.50
Erigeron peregrinus	1.2		9	3.60
Pyrola secunda	0.2	0.8	9	1.50
Senecio triangularis	0.2		9	0.60
Artemisia norvegica	T*		0	
Potentilla diversifolia	T		0	
Graminoids				
Carex nigricans	82.0	91.0	100	870.00
Luzula wahlenbergii	9.4	16.0	75	80.32
Juncus drummondii	2.3	4.2	42	21.39
Poa alpina	0.9		33	5.17
Deschampsia atropurpurea	0.2		9	0.60
Poa epilis	T		0	
Phleum alpinum	T		0	
BRYOPHYTES:				
Liverworts				
Lophozia sp.				
Scapania irrigua				
Mosses				
Brachythecium salebrosum				
Dicranum fuscescens				
Lescuraea incurvata				
Pogonatum alpinum				
Pohlia nutans				
Polytrichum juniperinum				
LICHENS:				
Cladonia pyxidata				
Solorina crocea				

* T = Trace

Other species with maximum prominence values in this community are *Veronica alpina*, *Ranunculus eschscholtzii*, *Juncus drummondii* and *Epilobium alpinum*.

Most vascular species in the *Carex nigricans* community are also present in the *Salix arctica - Antennaria lanata* community. Exceptions are *Vaccinium vitis-idaea* (whose presence was unexpected), *Arnica latifolia*, *Pyrola secunda* and *Senecio triangularis*. The presence and location of the last three species may be attributable to the proximity of a solifluction terrace community, as there is a shallow terrace adjacent to the upper W edge of the *Carex nigricans* stand.

Compared with other north slope communities, *Salix arctica* has the lowest prominence value here. It grows chiefly on the rock-based hummocks, as do the occasional *Deschampsia atropurpurea*, *Artemisia norvegica* and *Potentilla diversifolia*. The last three species, together with *Phleum alpinum*, are more common in the *Carex nigricans* community observed on the S slope.

Of the two liverworts present, *Scapania irrigua* is more common. *Brachythecium salebrosum* is the most abundant moss, *Pogonatum alpinum* and *Polytrichum juniperinum* the next most abundant. Both lichens are uncommon.

N. *SALIX NIVALIS* COMMUNITY

Habitat description

Salix nivalis has a rather unusual distribution pattern. It is generally more abundant in relatively dry, chionophobous communities, growing even on bare scree. It is rare in most chionophobous communities. However it forms small, rather dense carpets about 1 to 2 m^2 in size in some late snow - release areas, especially toward the NW portion of Signal Mountain. Such carpets were noted amongst boulders on the N slope, usually between communities dominated by *Cassiope tetragona* - *Dryas* (E) and by *Carex nigricans* (M) communities, and also on areas of finer substrate in protected trenches or draws.

Some observations (no quantitative analyses) were made at a *Salix nivalis* patch located toward the top of the NW Draw (see Fig. 3 for location). It was situated between *Cassiope tetragona* - *Dryas* dominated and *Salix arctica* - *Antennaria lanata* dominated communities (Plate 27). Because this draw is on the lee side of the main ridge, with respect to the prevailing wind direction, it is an area of high snow accumulation in winter. The *Salix nivalis* patch was not completely released from snow until July 2 in 1967, the *Salix arctica* - *Antennaria lanata* area several days later, and the *Carex nigricans* location almost two weeks later.

PLATE 27. Area near the top of the Northwest Draw, showing a *Salix nivalis* community on the right in autumnal colour (reddish), *Salix arctica* - *Antennaria lanata* community (grey) to the left of it, and a *Carex nigricans* communitv (brown) at the left of the photograph. An open unvegetated area (buff) is slightly to the left and below the *Salix nivalis* patch. All this is surrounded on three sides bv slightlv elevated micro-topographv dominated by *Cassiope tetragona* (dark green tufts) and *Dryas hookeriana*. A *Dryas* - moss community (greenish grey) is on the more elevated area at middle right.

The north end of Colin Range is in the distance, with Mt. Colin and Roche Bonhomme in the centre.

(Photographed August 31, 1967).

Wind- and water-deposited soil particles have also accumulated in this area This process was probably most active in late glacial times before the fine periglacial materials in the Jasper region were stabilized by vegetation to any degree. Boulders of varying sizes are common and many are at least partially buried in finer deposits.

Two soil pits were dug, one under the *Salix nivalis* mat and one under an adjacent unvegetated area. The content of silt-sized particles was very high in both profiles, especially in the former.

The soil under *Salix nivalis* was a mottled brown loam to 23 cm depth and a rather bright yellow silty loam from 23 to 50 cm depth. Both the colour and the texture of the latter are suggestive of loess. The presence of mottled shades of brown in the upper horizon and dark brown lenses in the lower horizon are probably indicative of cryoturbic processes. Roots were concentrated in the top 1 to 2 cm, with occasional roots sparsely distributed to a depth of 23 cm.

The profile under the unvegetated area also showed fine soil: greyish-buff clay loam in the top 18 cm and a yellow-brown-buff loam from 18 to 37 cm depth. Other than a few gravel and larger-sized stones "sorted" up onto the surface, particles greater than 2 mm were negligible within the soil. Sparsely distributed roots were present from 5 to 23 cm depth. The pH values of soils from both pits were among the highest

of all samples collected from Signal Mountain.

A microenvironmental station (ME-5) was located on the *Salix nivalis* mat (see Plate 5). Both the air and soil temperatures recorded here were comparatively low, especially during July while there was snow in the draw. The lowest wind velocities were recorded here.

Vegetation

Salix nivalis is by far the predominating species, with *Antennaria lanata* the second most abundant. *Salix arctica* is present but not abundant. Other species present are: *Sibbaldia procumbens*, *Juncus drummondii*, *Pedicularis lanata*, *Artemisia norvegica*, *Potentilla diversifolia*, *Campanula lasiocarpa*. *Erigeron peregrinus*, *Poa alpina*, *Trisetum spicatum* and several *Carex* species (chiefly *C. nigricans*). In other areas, *Castilleja occidentalis* is also common. All the above species are present in the *Salix arctica* - *Antennaria lanata* community (L), and perhaps the *Salix nivalis* community might be considered a variant of it, with *S. nivalis* substituting for *S. arctica*.

Cryptograms were present but not collected from this site.

O. NIVATION HOLLOWS VEGETATION

Habitat Description

Several areas on the N slope of Signal Mountain have a snow cover lasting up to 10 or 11 months of the year. The topography is generally depressional due to differential weathering of softer bedrock, and nivation processes tend to cause further erosion of the substrate. Boulders are common (e.g., Plate 28) but finer materials are also present. No soil pit was dug, but the surface appeared very sandy.

The nivation hollows are relatively barren of vegetation due chiefly to the extremely short growing season. There are also other contributing factors. Even when plants have become established their existence remains precarious. For example, they may be washed away by late summer storms. Observations were made in these areas some time after the severe storm of August 5, 1969. The finer soil materials had been thoroughly washed down and rilled. Only a few mosses and very occasional vascular plants were found on the downslope side of boulders.

Another factor is a biotic one. White-tailed ptarmigan (*Lagopus leucurus*) hens and young were observed several times as they foraged here for food in August. They appeared to favour the tender young shoots of forbs growing in this area over the graminoids here and over older vegetation elsewhere.

PLATE 28. Typical nivation hollow in the North Draw on Signal Mountain. The ground is mostly bare, as only a few species are able to survive the one to two month growing season available in such an area. A *Carex nigricans* community lies immediately below the bare area, with dark green areas beyond dominated by *Cassiope tetragona*. In the left foreground is a rocky and hummocky transitional community dominated by the *Salix arctica - Antennaria lanata* type.

The Victoria Cross Ranges, including Pyramid Mountain, are in the distance.

(Photographed September 3, 1967).

Vegetation

Vegetation is sparse and patchy in nivation hollows, consisting of occasional plants, or clumps of plants, which can survive the very short growing season. Probably the most common species are *Oxyria digyna, Epilobium alpinum* and the moss *Polytrichum norvegicum. Ranunculus pygmaeus* and *Saxifraga adscendens* are also characteristic of and confined to these very late snowbeds.

Species that are occasionally found include *Arenaria sajanensis, Stellaria calycantha Cardamine bellidifolia, Saxifraga aestivalis, S. rivularis, Sibbaldia procumbens, Potentilla diversifolia, Artemisia norvegica, Antennaria lanata, Erigeron humilis, E. peregrinus, Poa alpina, Deschampsia atropurpurea, Carex nigricans, C. nardina* and *Juncus biglumis*. Many of these plants were seen in the vegetative state, some were in bud, and only a few were in flower and in fruit in 1967. Most cannot develop beyond the vegetative state during summers preceded by normal or heavy winter snowfall. However, because they are perennial, some of them may produce flowers and seed during warm summers preceded by winters with low winter snowfall.

No lichens were observed, but mosses were at least as common as vascular plants. Unfortunately, the main bryophyte collection from this community type was lost.

INTERRELATIONSHIPS OF PLANT COMMUNITIES

The communities recognized and analyzed on Signal Mountain have been ranked according to Indices of Similarity with each other, arranged in sequence with the most similar next to each other (see Table 13, Fig. 14), and described in that order. Two other methods for showing vegetational relationships between communities were found useful. One is a phytosociological table with species grouped according to the communities in which they were found (Table 38), somewhat akin to the association tables of the Zurich-Montpellier school (Braun-Blanquet 1932). The other is an ordination of plant communities (Fig. 15) as developed by the Wisconsin school and used by many North American ecologists. All but the most insignificant species were used in preparing the table and ordination.

Phytosociological Table

With the phytosociological table (Table 38) it is possible to show the ecological amplitudes and inter-specific associations of many species expediently. Three main groupings of species emerge from this table:

(1) Chionophobes - species with comparatively narrow tolerance ranges occurring in areas of little snow accumulation and early snow release (communities AA to E);

(2) Chionophiles - species which also exhibit comparatively narrow tolerance ranges but inhabiting areas of greater snow accumulation and later snow release (communities D to O);

and (3) Alpine Constants - species with ecological amplitudes wide enough to tolerate conditions in most if not all communities in the alpine zone.

Among the Alpine Constants *Artemisia norvegica* is present in all communities, thus exhibiting the widest ecological amplitude of all species found on Signal Mountain. *Potentilla diversifolia* and *Salix arctica* are almost as widely distributed as *Artemisia*. Other species which may be regarded as Alpine Constants, although absent from several communities, are: *Campanula lasiocarpa, Polygonum viviparum, Salix nivalis, Arenaria sajanensis, Poa alpina, P. arctica, Gentiana prostrata* and *Vaccinium vitis-idaea*.

The dominant species in the chionophobic group is *Dryas hookeriana*. *Salix arctica*, although classed as an Alpine Constant, is much more prominent and the overall dominant species in the chionophilic group. The ordination (Fig. 15) further substantiates the involvement of these two species in the differentiation of the main groups of alpine plant communities.

Further divisions may be made in the Chionophobe and Chionophile groups. Species allied with *Dryas* may be divided in to two subgroups: (a) the extremely chionophobous species (p. 190), and (b) chionophobous species with wider ecological amplitudes; the latter includes *Dryas*. It was noted that wherever *Dryas* occurs it is usually the primary or occasionally the secondary dominant; this can be said of

no other alpine species.

South slope communities can be associated with chionophoby and their species grouped according to the degree of snow cover. However, the opposite criterion, based on dependable snow cover, does not adequately account for the diversity of north slope communities as other influential factors complicate the vegetation pattern on the north slope. Nevertheless, the ecological relations and species affinities of north slope communities do show in the phytosociological table.

Communities J, K and L are all in areas of fairly late snow release and, in addition, are probably the moistest group on the north slope during the growing season. Bryophyte prominence values are highest in these mesophytic communities (Table 39).

Graminoid prominence increases progressively in communities J, K and M. The single growth form has the highest prominence values in communities H, J, K and L.

Of the vascular plant growth forms, dwarf shrubs are important in all communities except M and are dominant in 7 of the 12 analyzed communities (A, C, D, E, F, G and J); forbs are dominant in H, K and L; and graminoids dominate in B and M.

Community K is the only one in which bryophytes (mosses) are more prominent than vascular plants.

TABLE 38. PHYTOSOCIOLOGICAL TABLE SHOWING SUMMARY OF PRESENCE AND PROMINENCE VALUES[1] FOR SELECTED VASCULAR SPECIES OF SIGNAL MOUNTAIN ALPINE PLANT COMMUNITIES.

	SOUTH				NORTH SLOPE										
	COMMUNITY TYPE														
SPECIES	CUSHIONS	*DRY.* ISLANDS	*DRY.*-GRAM.	*DRY.-KOBR.*	*DRY.*-LICHEN	*DRY.*-MOSS	*CASS.T.-DRY*	*DRY.-EMPET.*	*DRY.-SLX.A.*	*CASS.-PHYL.*	*SLX.A.-ARCT.*	*SLX.A.-ANT.*	*CAREX NIGR.*	*SLX. NIVAL.*	HOLLOWS
	(AA)	A	B	C	D	E	F	G	H	J	K	L	M	(N)[2]	(O)[2]
CHIONOPHOBES:															
Saxifraga bronchialis	P[3]														
Saussurea densa		1	1												
Crepis nana		T[4]	1												
Astragalus alpinus			1												
Pedicularis flammea			1												
Ranunculus gelidus		1	-[5]	1											
Pedicularis oederi				1											
Myosotis alpestris		2	2	T	1										
Oxytropis campestris		T	1	1	T										
Kobresia bellardii				97	21										
Saxifraga oppositifolia					3										
Draba nivalis	P	1	1	-	1										
Anemone drummondii	P	1	-	-	1										
Oxytropis podocarpa	P	13	23	1	16	T									
Potentilla nivea	P	4	8	6	3	T									
Campanula unifloria		1	5	1	3	1									
Selaginella densa		11	-	9	21	1									
Festuca baffinensis	P	2	-	-	1	1									
Arnica alpina		1	2	1	1	3									

TABLE 38. (Cont'd.)

	(AA)	A	B	C	D	E	F	G	H	J	K	L	M	(N)	(O)
CHIONOPHOBES (less restricted):															
Agropyron latiglume	P	1	59	-	4	-	4								
Antennaria alpina	P	4	2	1	1	8	3	2							
Trisetum spicatum	P	-	-	13	-	-	1	1							
Luzula spicata		T	-	-	-	1	-	3							
Carex petricosa			40	-	-	11	-	1							
Festuca brachyphylla			54	-	-	-	-	2							
Solidago multiradiata		1	11	2	-	1	-	T	36						
Setllaria monantha		1	1	1	1	-	1	-	T						
Gentianella propinqua		1	5	-	T	-	-	-	1						
Silene acaulis		1	25	2	30	12	1	T	3						
Dryas hookeriana		99	190	249	247	283	114	230	130						
ALPINE CONSTANTS:															
Gentiana prostrata		T	7	2	1	1	-	-	15	-	T				
Polygonum viviparum		2	30	4	5	18	10	13	17	8	27	30			
Campanula lasiocarpa		4	1	1	8	8	17	3	30	5	14	29	-	P	
Artemisia norvegica		T	14	1	1	1	17	30	47	51	69	77	T	P	P
Potentilla diversifolia		1	18	1	1	2	-	-	13	12	10	8	T	P	P
Poa alpina		1	2	T	1	-	2	1	-	-	-	3	5	P	P
Arenaria sajanensis		1	-	-	1	1	1	T	1	-	-	9	-	-	P
Salix nivalis		19	23	26	81	51	40	3	-	1	-	-	7	P	
S. arctica			12	1	2	21	24	81	78	56	157	230	4	P	
Vaccinium vitis-idaea			T	-	2	3	1	59	-	-	-	-	2		
Poa arctica			6	2	2	2	1	1	2	-	1				
CHIONOPHILES (less restricted):															
Pedicularis lanata					2	1	2	-	-	-	-	8	-	P	
Cassiope tetragona					T	13	304	2	13	-	2	12			
Pedicularis capitata					T	9	1	-	1	7					
Potentilla hyparctica						2	-	1	-	-	1				

TABLE 38. (Cont'd.)

	(AA)	A	B	C	D	E	F	G	H	J	K	L	M	(N)	(O)
<u>CHIONOPHILES</u>:															
Carex nigricans							2	-	-	-	-	2	879	P	P
Gentiana glauca							7	T	-	-	-	3			
Lycopodium selago							T	T	-	-	-	T			
Phyllodoce gladuliflora							T	4	-	136	-	T			
P. empetriformis								4	-	-	-	T			
Empetrum nigrum								131							
Calamagrostis inexpansa								28							
Carex spectabilis									29	59					
Anemone parviflora									10	3					
Trollius albiflorus									3	20					
Deschampsia caespitosa									1	1	38				
Senecio triangularis									34	3	-	-	1		
Pyrola secunda									5	11	-	-	2		
Arnica latifolia									20	46	-	1	10		
Veronica alpina									9	10	7	30	37		
Castilleja occidentalis									4	T	-	27	-	P	
Erigeron peregrinus									43	17	-	45	4	P	P
Sibbaldia procumbens									3	6	-	46	12	P	P
Antennaria lanata									1	27	-	170	1	P	P
Epilobium alpinum										11	-	1	18	-	P
Deschampsia atropurpurea										1	-	8	1	-	P
Ranunculus eschscholtzii										3	10	8	35		
Luzula wahlenbergii										T	-	15	80		
Poa epilis										1	-	8	T		
Cassiope mertensiana										249	-	40			
Phleum alpinum										2	T				
Vaccinium scoparium										3					

TABLE 38. (Cont'd.)

	(AA)	A	B	C	D	E	F	G	H	J	K	L	M	(N)	(O)
CHIONOPHILES (cont'd.):															
Arctagrostis arundinacea											149				
Equisetum scirpoides											95				
Carex phaeocephala											60				
Petasites frigidus											36				
Juncus castaneus											8				
Eriophorum scheuchzeri											2				
Cardamine bellidifolia											1	-	-	-	P
Saxifraga aestivalis											T	-	-	-	P
Carex microglochin												12			
Lycopodium alpinum												8			
Hieracium gracile												9	6		
Juncus drummondii												3	21	P	
Oxyria digyna															P
Ranunculus pygmaeus															P

[1] PROMINENCE VALUE = % cover X $\sqrt{\%\ \text{Quadrat Frequency}}$

[2] ( ) Community not analyzed quantitatively

[3] P = Present; no quantitative data

[4] T = Trace

[5] - Not recorded.

TABLE 39. PHYSIOGNOMIC COMPARISON OF SIGNAL MOUNTAIN ALPINE PLANT COMMUNITIES (USING PROMINENCE VALUES).

	COMMUNITY TYPE											
	DRYAS ISLANDS	*DRYAS*-GRAMINOID	*DRYAS-KOBRESIA*	*DRYAS*-LICHEN	*DRYAS*-MOSS	*CASS. T.-DRYAS*	*DRYAS-EMPETRUM*	*DRYAS-SALIX A.*	*CASS. M.-PHYLL.*	*SALIX A.-ARCT.*	*SALIX A.-ANTEN.*	*CAREX NIGRICANS*
	A	B	C*	D	E*	F*	G	H	J	K	L	M
Vascular Plants	210	590	500	647	580	790	670	664	950	700	810	1000
Dwarf Shrubs	144	200	300	388	530	790	570	370	660	230	380	8
Compact Forbs**	39	59	28	120	17	12	5	54	48	146	260	60
Single-growing Forbs	16	110	13	35	60	77	74	420	277	230	290	95
Graminoids	8	300	114	95	38	21	48	84	330	360	120	980
Bryophytes	9	173	94	124	200	70	283	125	510	850	460	190
Lichens	60	18	64	260	50	98	150	54	12	28	340	4
Unvegetated	724	400	92	147	70	T	217	T	2	138	9	11

T = Trace amount

* Prominence Values calculated by multiplying estimated cover scale and quadrat frequency; all others based on cover points multiplied with quadrat frequency.

** Forbs growing in mats, cushions, rosettes or tufts.

Salix arctica is the primary dominant among vascular species in two of the twelve analyzed communities (K and L), second in one (H), third in three (D, E and G), and fourth in two (F and J). The *Carex nigricans* meadow (M) is the only N slope community in which *Salix arctica* is unimportant; it also includes fewer constant species than any other community and is the most isolated community type on the ordination (see below).

Of the chionophilous species, *Cassiope tetragona* exhibits the widest tolerance range, and *Pedicularis lanata* appears to have closely similar requirements.

The *Salix arctica - Arctagrostis* community (K) occupies the wettest site and is the poorest "fitting" community in the basically unidimensional species arrangement in the phytosociological table. This is well illustrated in the ordination which follows. Not only does K lack many species present in adjacent communities (J and L), it has several species not found in any other community.

The *Dryas - Salix arctica* (H) and *Cassiope mertensiana - Phyllodoce glanduliflora* (J) communities are associated with solifluction terraces, are geographically adjacent to each other, but have different primary and secondary dominants. However, they have many less-prominent species in common.

The above discussion of Table 38 is chiefly based on species presence. Community relationships based on species

abundance as well as presence are shown in the Indices of Similarity between communities and ordinations derived from them.

Ordination

Because the alpine plant communities of Signal Mountain frequently intergrade, the ordination technique devised by Bray and Curtis (1957) and modified by Beals (1960) seemed appropriate to (1) show the relationships between analyzed communities, and (2) predict the structure, composition and ecology of unsampled intermediate communities.

Using 94 of the 108 vascular species found in the analyzed communities, several ordinations were constructed using the Bray and Curtis and the Orloci (1966) methods. There was a marked similarity between all the ordinations. The one chosen for presentation here (Fig. 15) gave the highest Pearson's Correlation Coefficient ("r" = 0.87) between the 66 Indices of Dissimilarity (100 - I_{sim}) and the actual ordination distances between communities. This ordination was constructed according to the Bray and Curtis method. (For construction method see Beil 1966 or Stringer 1966.)

Communities C (*Dryas - Kobresia*) and M (*Carex nigricans*) were chosen as the end stands of the X-axis which is 99.9 units in length; communities A (*Dryas* islands) and K (*Salix arctica - Arctagrostis*) were chosen as the end stands of the

Y-axis which is 98.6 units long. Only two axes are used as this was deemed sufficient for twelve communities, and considering the high "r" value. The coordinates of the communities are given below.

COMMUNITY	LOCI X	LOCI Y
A. *Dryas* islands	15.1	0.0
B. *Dryas* - graminoid	12.7	26.7
C. *Dryas* - *Kobresia*	0.0	15.1
D. *Dryas* - lichens	3.9	14.4
E. *Dryas* - moss	6.7	25.8
F. *Cassiope tetragona* - *Dryas*	25.1	30.7
G *Dryas* - *Empetrum*	14.9	43.9
H. *Dryas* - *Salix arctica*	28.1	49.9
J. *Cassiope mertensiana* - *Phyllodoce*	51.4	66.2
K. *Salix arctica* - *Arctagrostis*	51.1	98.6
L. *Salix arctica* - *Antennaria lanata*	56.7	78.7
M. *Carex nigricans*	99.9	51.6

Because the two end stands of the Y-axis (A and K) are not equidistant from the two end stands of the X-axis (C and M), the Y-axis is skewed to form an angle of 69° with the X-axis. The positions of all stands have been plotted accordingly.

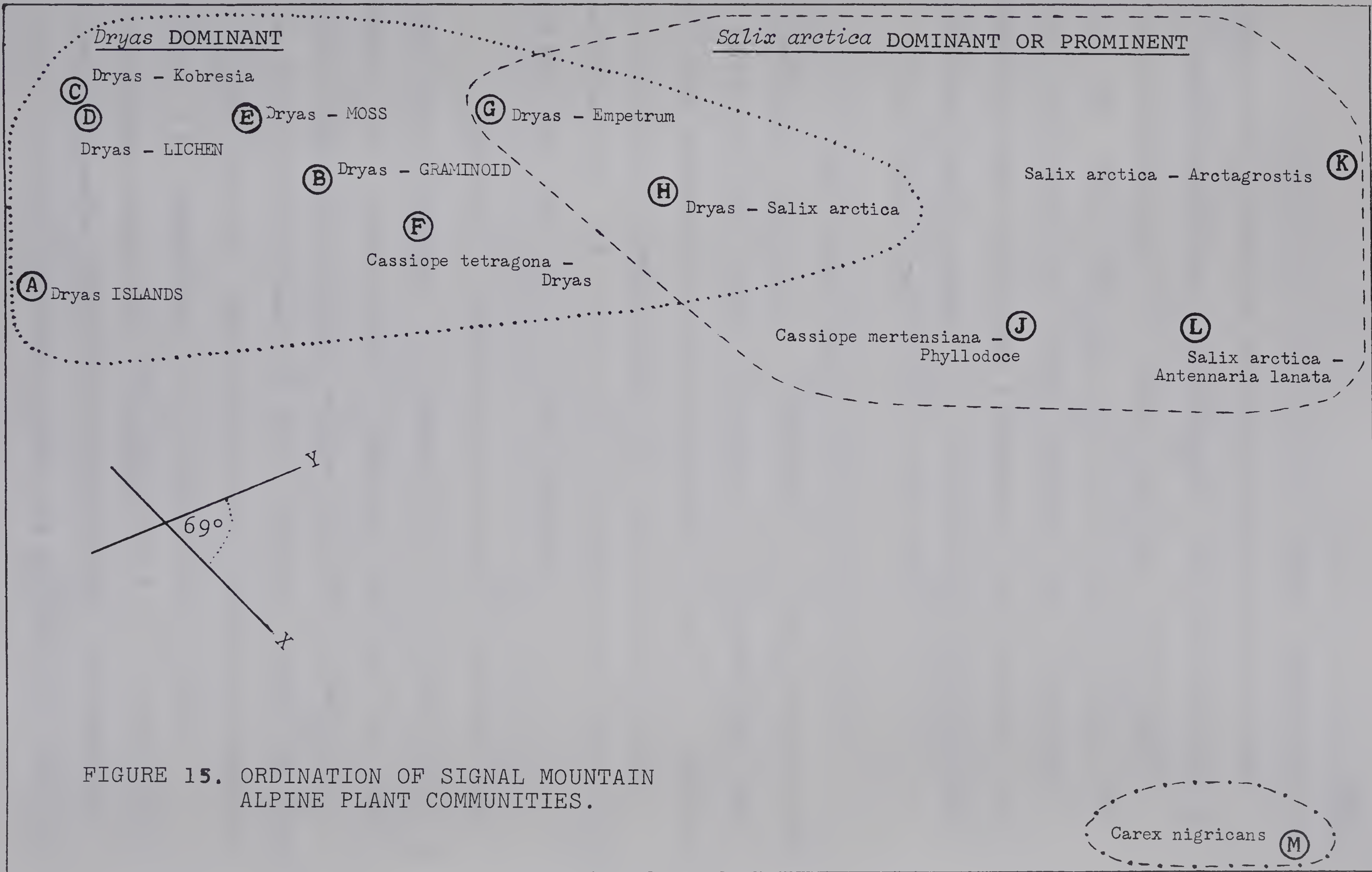


FIGURE 15. ORDINATION OF SIGNAL MOUNTAIN ALPINE PLANT COMMUNITIES.

The vegetational relationships between communities are shown by the ordination patterns of three major species: (1) *Dryas hookeriana*, a Chionophobe; (2) *Salix arctica*, an Alpine Constant; and (3) *Carex nigricans*, a Chionophile (Fig. 15). While the *Dryas* and *Salix* groups overlap, the *Carex*, consisting of a single community (M), is distinct from the other two but has a somewhat closer affinity with the *Salix arctica* group. This relationship was also shown in the phytosociological table (Table 38).

Environmental gradients appear strongly on the vegetational ordination. Gradients of two main factors are aligned with the X-axis: (1) nature of the topography, and (2) snow accumulation and release dates (Fig. 16). Gradients of air and soil temperatures, soil texture and available moisture (Figs. 18, 19, 20, 21) all appear to be more or less aligned with the Y-axis of the ordination.

Correlation of topography and community pattern shows three main groupings: (1) communities A, C, D and E occur in areas with a large amount of exposure resulting from rather convex topography (stands representing these communities are also related because of their locations toward the W end of Signal Mountain, subjecting them to prevailing W and SW winds); (2) communities J, K, L and M occur in more depressional areas; and (3) communities B, F, G and H are found on somewhat uneven or topographically intermediate sites, including patterned ground and solifluction terraces.

FIGURES 16-21. ENVIRONMENTAL GRADIENTS PLOTTED ON ORDINATION OF SIGNAL MOUNTAIN ALPINE PLANT COMMUNITIES.

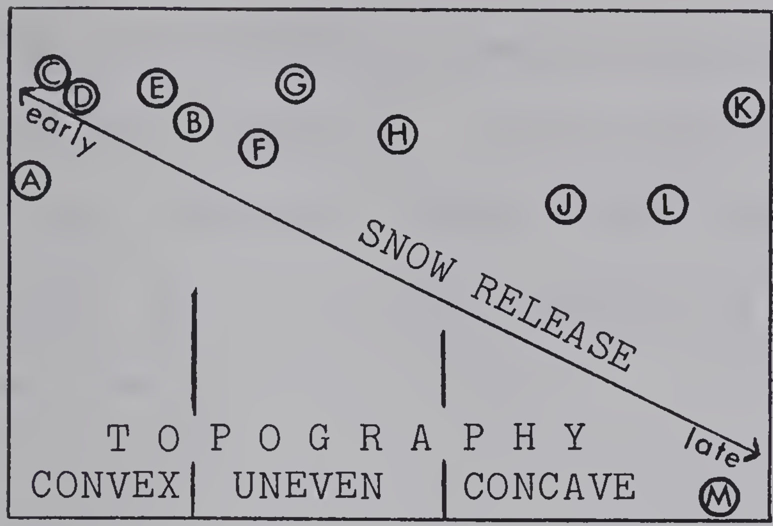


FIG. 16. SNOW RELEASE AND TOPOGRAPHY OF SITES

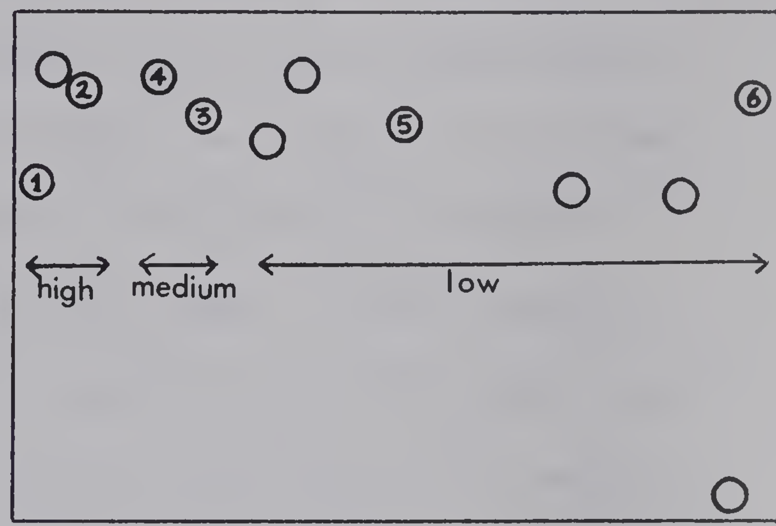


FIG. 17. MEAN PREVAILING WIND VELOCITY RANK (SEE TABLE 10)

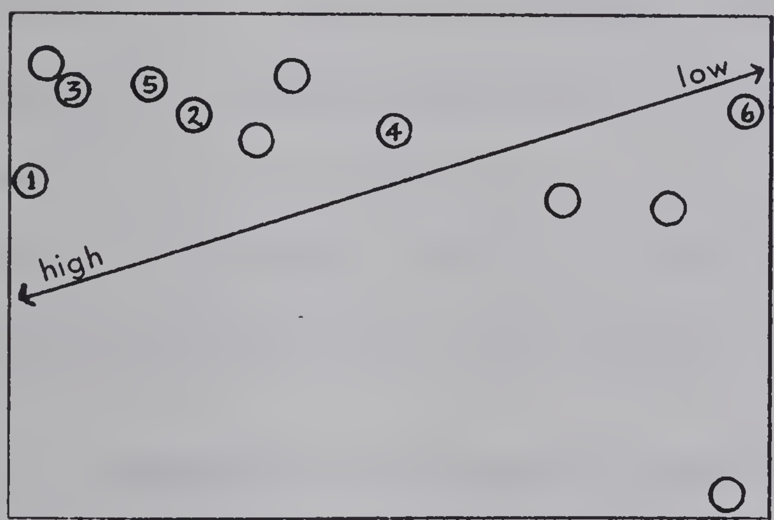


FIG. 18. MEAN AIR TEMPERATURE RANK (SEE TABLES 5 AND 6)

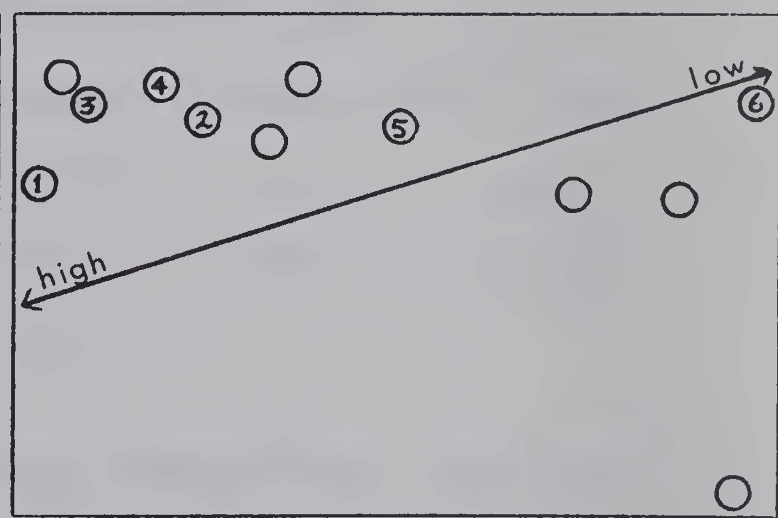


FIG. 19. SOIL TEMPERATURE RANK (SEE TABLE 7)

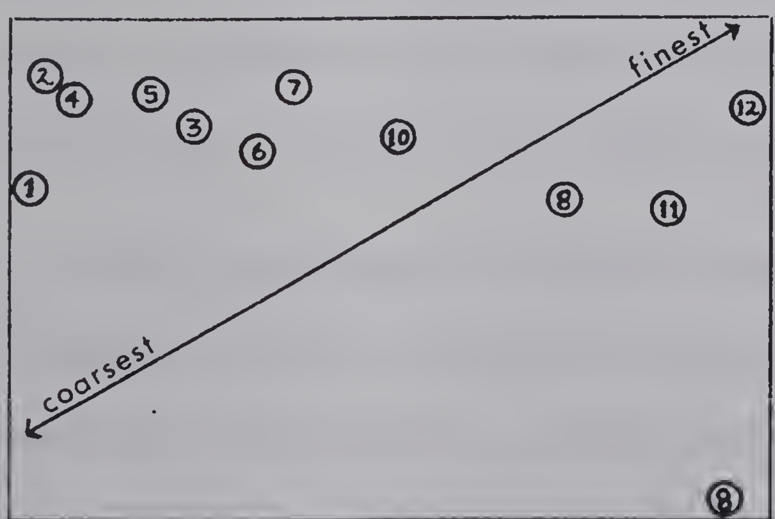


FIG. 20. SOIL TEXTURE RANK (SEE TABLE 11)

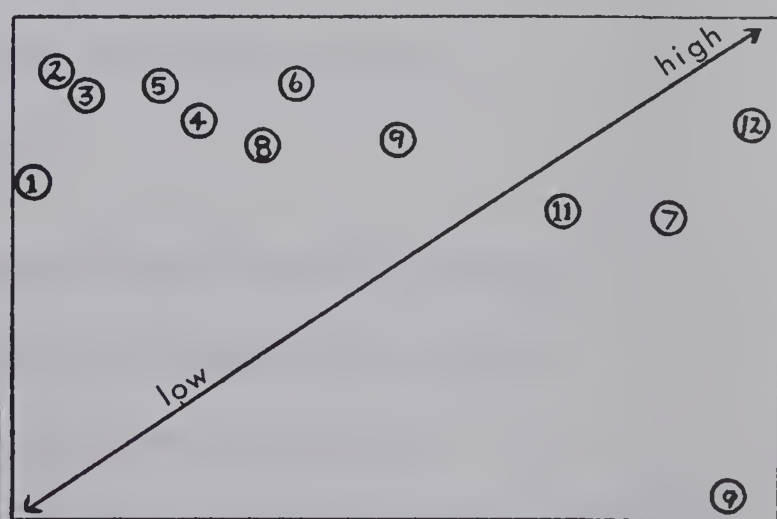


FIG. 21. AVAILABLE MOISTURE RANK AT 10 CM DEPTH (SEE TABLE 11)

Note: Blank circles denote no data.

Although no measurements of snow depth were made, a high correlation between topography and snow accumulation would be expected. Snow release dates were noted for some of the community types, particularly the early and late sites, but are rather conjectural for some of the central portion of the gradient. In this case, the ordination may be particularly useful in predicting conditions at community sites.

Wind and temperature data are also incomplete (Figs. 17, 18, 19) and the ranking of the blanks might also be generally predicted by the ordination. Wind velocity may not be truly gradational, but communities usually exposed to high or moderate winds are distinct from those generally experiencing lower wind speeds (Fig. 17).

Gradients of mean air and soil temperature are very similar to each other and appear to be highly correlated with soil texture and available soil moisture (Figs. 20, 21). The soil texture gradient (based on gravel + sand: silt + clay) is probably the best fitting gradient on the ordination, except for community B.

Superposition of lines representing environmental gradients on the ordination diagrams shows that Signal Mountain's location, orientation and geology have contributed to lower snow accumulation, earlier snow release, higher air and soil temperatures, higher winds, coarser soils and greater moisture stress in communities on the left

side, while the opposite is generally true of communities on the right side.

Dryas-dominated communities are more closely grouped together in the ordination than are those dominated by *Salix arctica*. The latter are generally N slope communities while the former occupy either N or S slopes. The *Carex nigricans* community, which is much more isolated, is chiefly found on N slopes. Two outstanding characteristics of this *Carex* community are very late snow release and very low species diversity. Species diversity, however, does not appear to form a gradient on the ordination.

Community A (*Dryas* islands) is rather isolated from other communities dominated by *Dryas*. Some of the characteristics which contribute to this isolation include the lowest vegetation cover, intense insolation, the highest air and soil temperatures, the greatest wind velocity, early snow release, the coarsest and most unstable substrate, low available soil moisture and probably the highest moisture stress during much of the growing season.

Community K (*Salix arctica - Arctagrostis*) is another somewhat isolated community in the ordination. It has the largest number of species not found in other community types. It is also the wettest and coldest site, with the finest soil texture. Unfortunately the snow release date for this community is not known. It is suspected that the addition of a third axis to the ordination would further

isolate this community from the others.

The two most similar communities vegetationally are *Dryas* - *Kobresia* (C) on the SW slope and *Dryas* - lichen (D) of the ridge top (I_{sim} = 73.7%, see Table 13, p. 84). Environmental conditions would, therefore, be expected to be very similar. Community D does have greater microtopographic relief, may not have as much wind at the ground level, and the soil is thinner and coarser.

The *Dryas* - graminoid community (B) does not completely fit the environmental gradients in the two-dimensional ordination and the addition of another axis would probably give it a more representative location. Although its situation in the ordination diagram is probably correct on the snow release gradient (X-axis), its position on the other gradients (Y-axis) would appear to be more correct to the left of community E, according to its rank in Figs. 16-21.

The superposition of physiognomic data on the ordination (Figs. 22-28) implies their probable relations with environmental factors (Figs. 16-21). Dwarf shrubs are prominent in all but the *Carex nigricans* community (M), suggesting that they depend on relatively early snow release (Fig. 22). Forbs are prominent in the four most mesic communities (H, J, K, L). Bryophyte prominence (Fig. 23) also appears to be related to moisture.

FIGURES 22-44.

VEGETATION VARIABLES PLOTTED ON ORDINATION OF SIGNAL MOUNTAIN ALPINE PLANT COMMUNITIES.

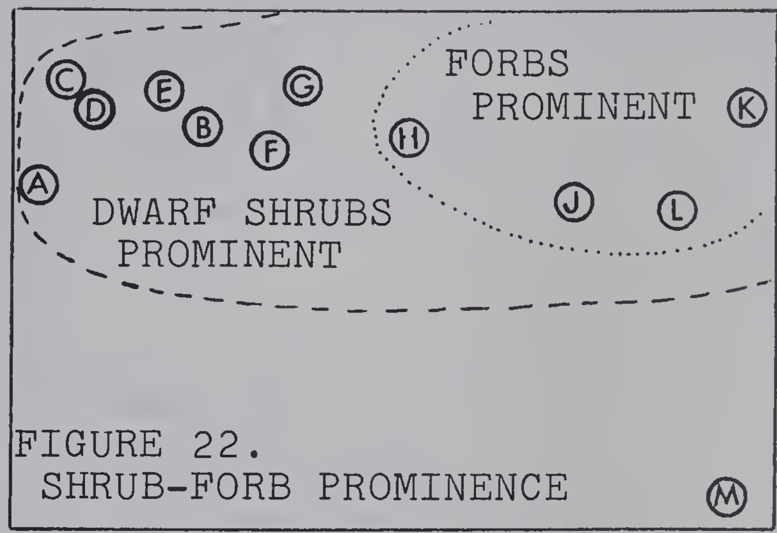


FIGURE 22.
SHRUB-FORB PROMINENCE

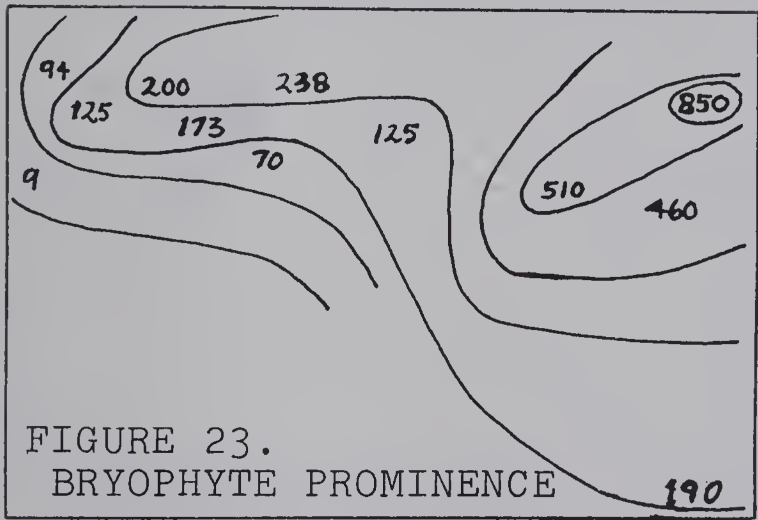


FIGURE 23.
BRYOPHYTE PROMINENCE

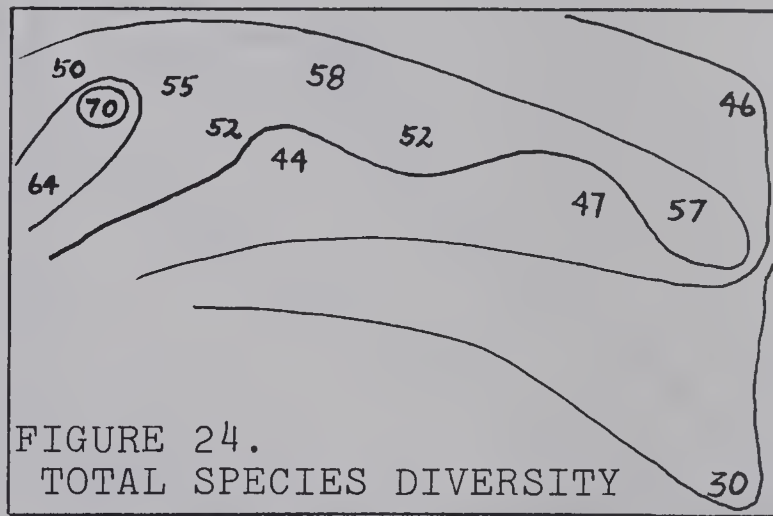


FIGURE 24.
TOTAL SPECIES DIVERSITY

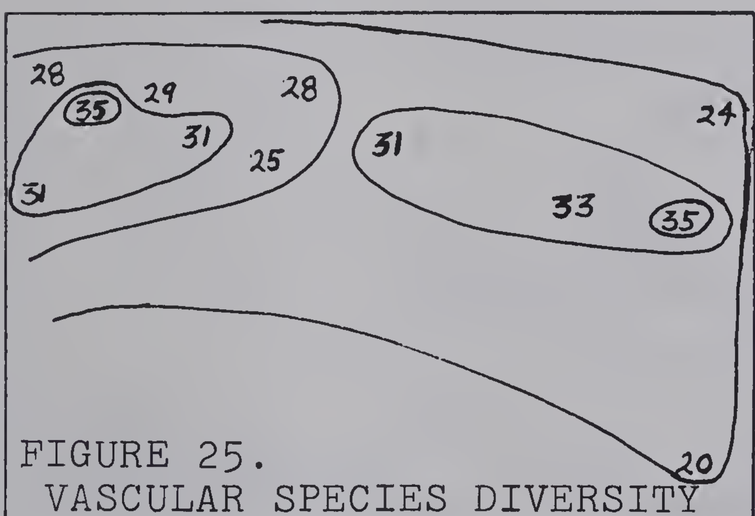


FIGURE 25.
VASCULAR SPECIES DIVERSITY

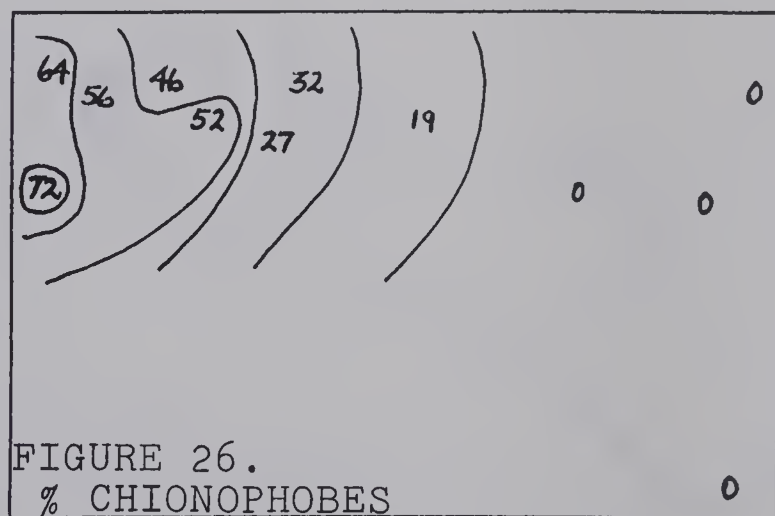


FIGURE 26.
% CHIONOPHOBES

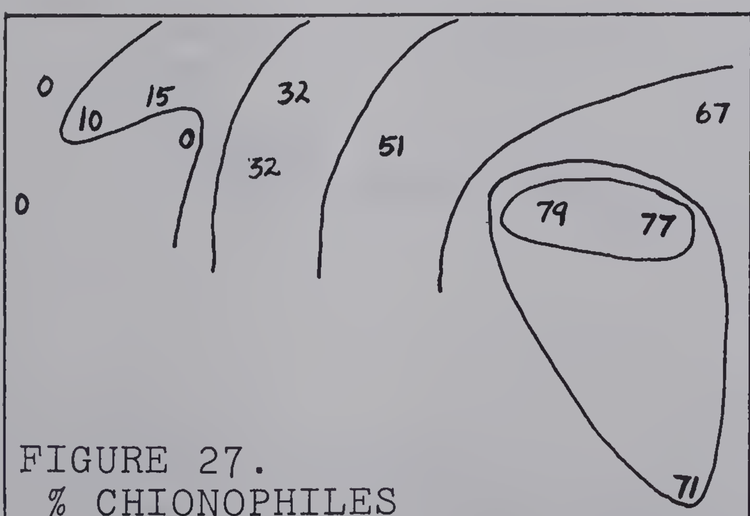


FIGURE 27.
% CHIONOPHILES

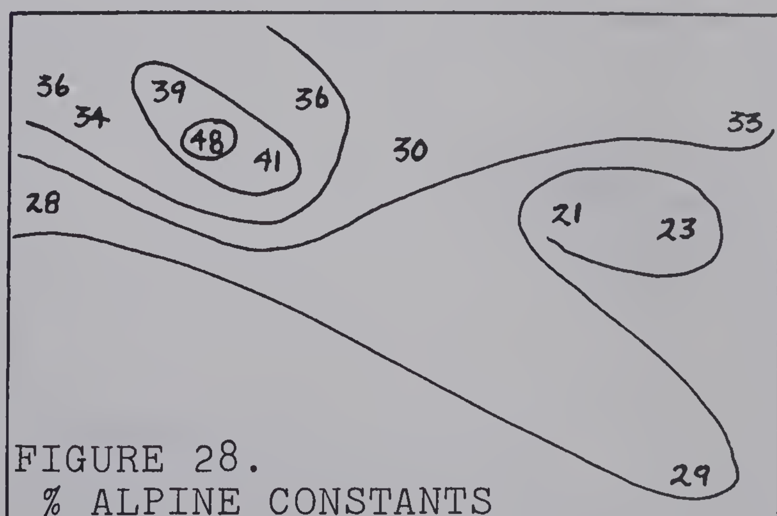


FIGURE 28.
% ALPINE CONSTANTS

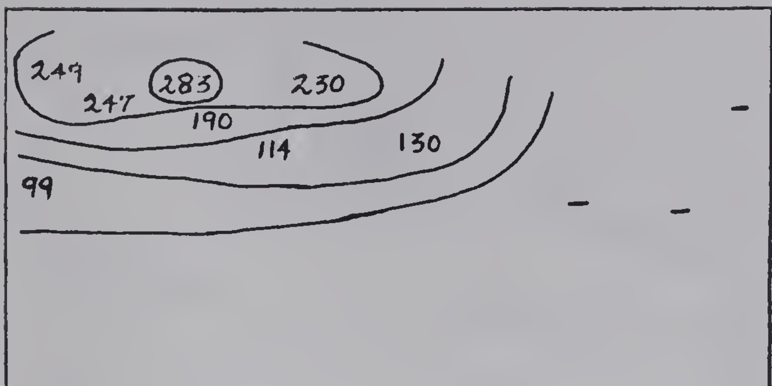


FIGURE 29.
DRYAS HOOKERIANA

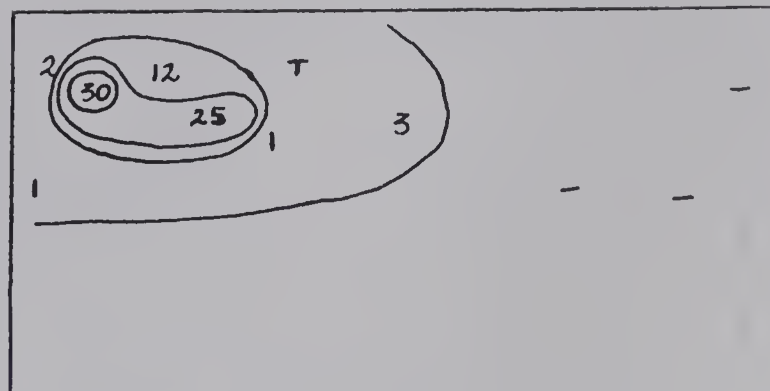


FIGURE 30.
SILENE ACAULIS

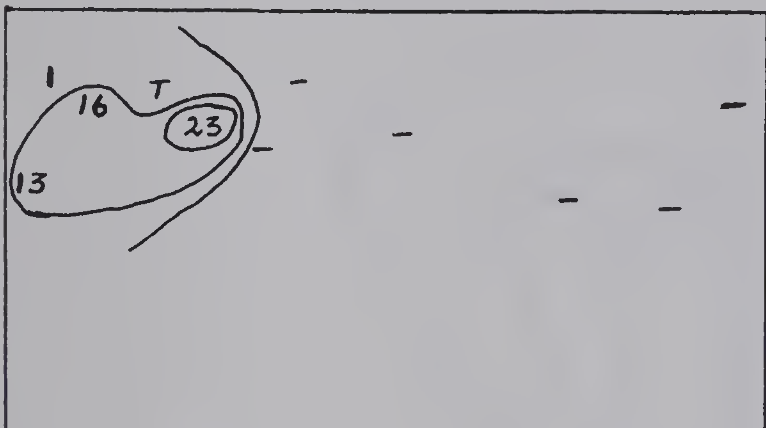


FIGURE 31.
OXYTROPIS PODOCARPA

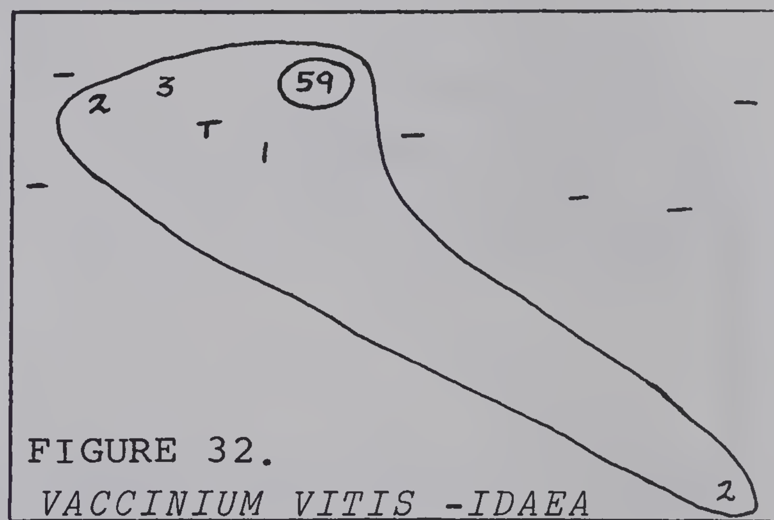


FIGURE 32.
VACCINIUM VITIS -IDAEA

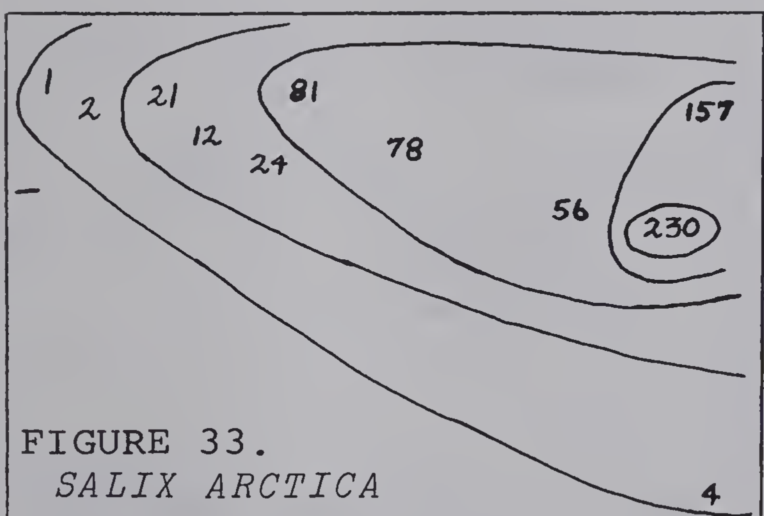


FIGURE 33.
SALIX ARCTICA

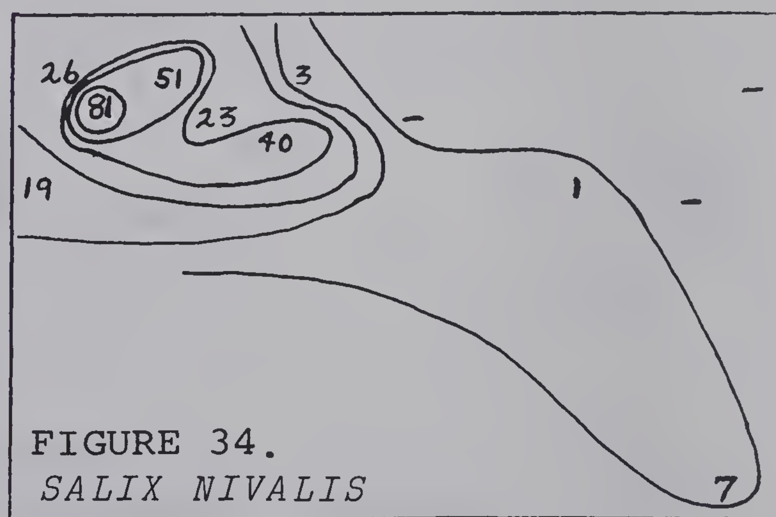


FIGURE 34.
SALIX NIVALIS

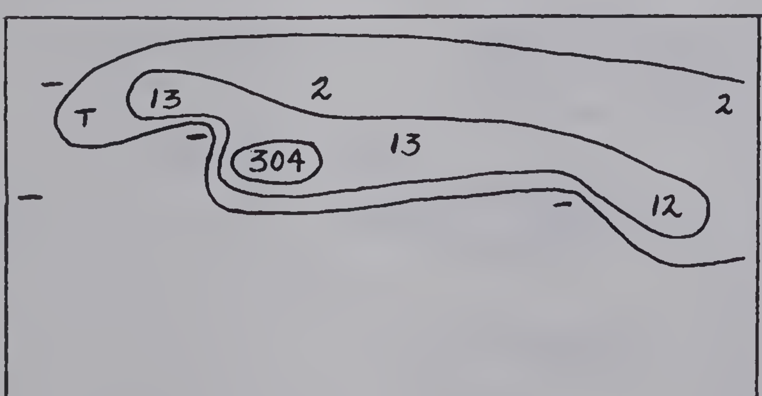


FIGURE 35.
CASSIOPE TETRAGONA

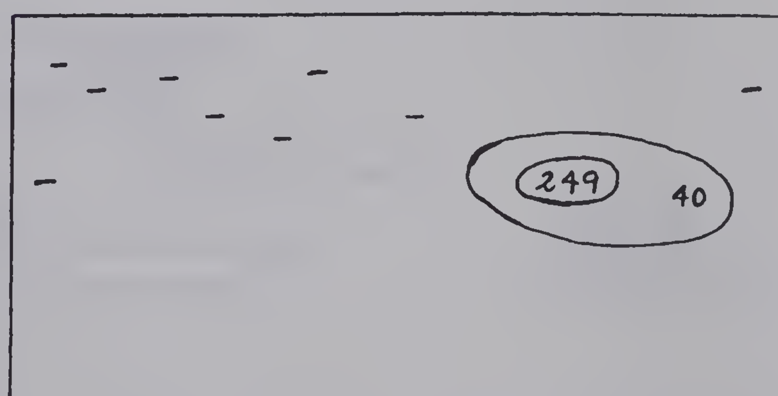


FIGURE 36.
CASSIOPE MERTENSIANA

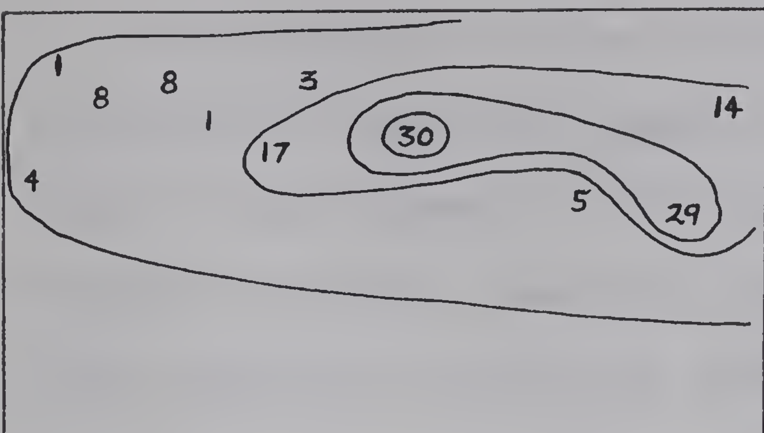


FIGURE 37.
CAMPANULA LASIOCARPA

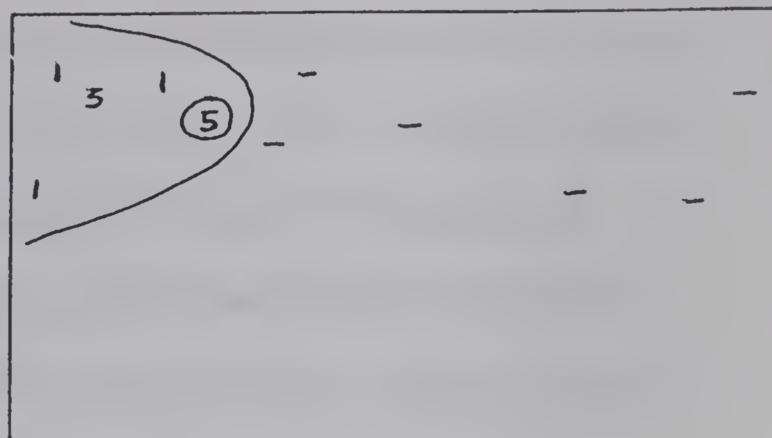


FIGURE 38.
CAMPANULA UNIFLORA

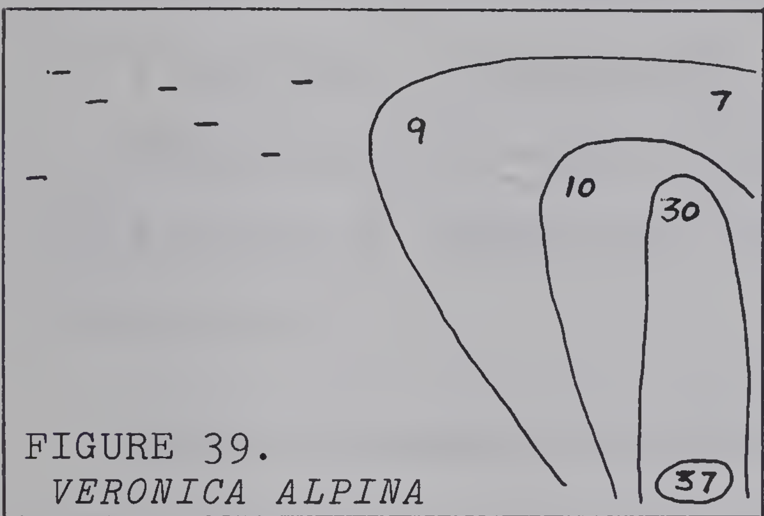


FIGURE 39.
VERONICA ALPINA

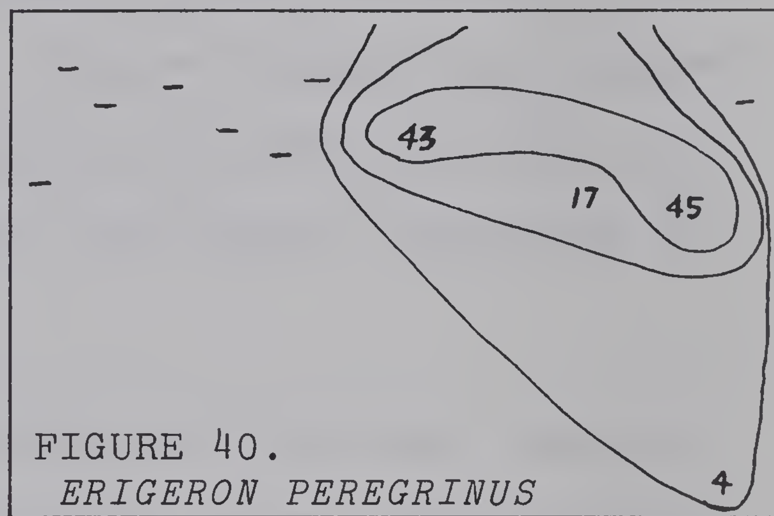


FIGURE 40.
ERIGERON PEREGRINUS

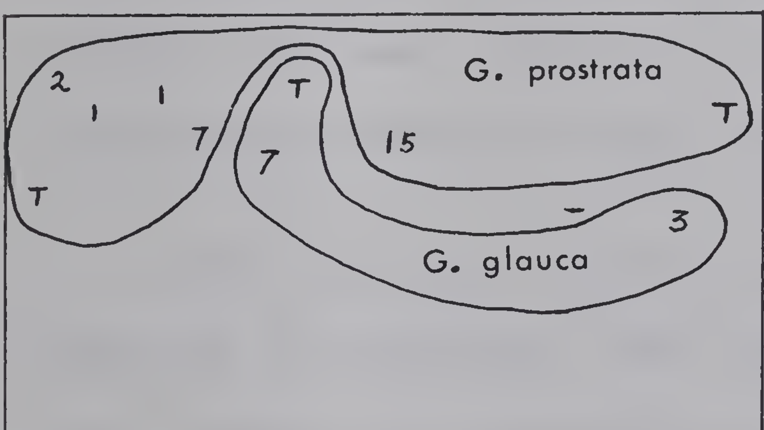


FIGURE 41.
GENTIANA SPECIES

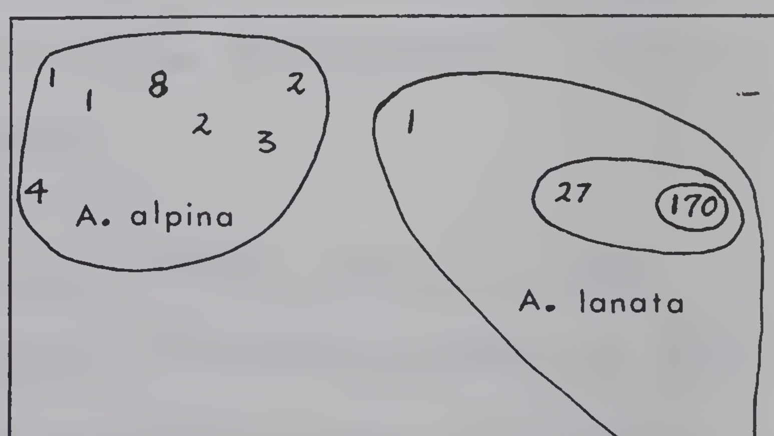


FIGURE 42.
ANTENNARIA SPECIES

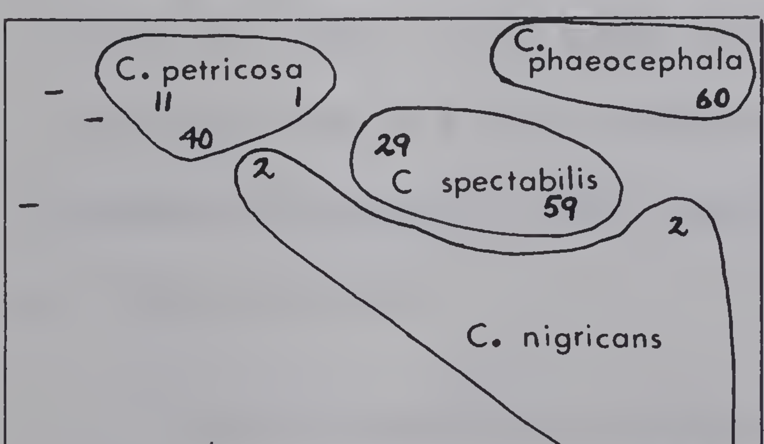


FIGURE 43.
CAREX SPECIES

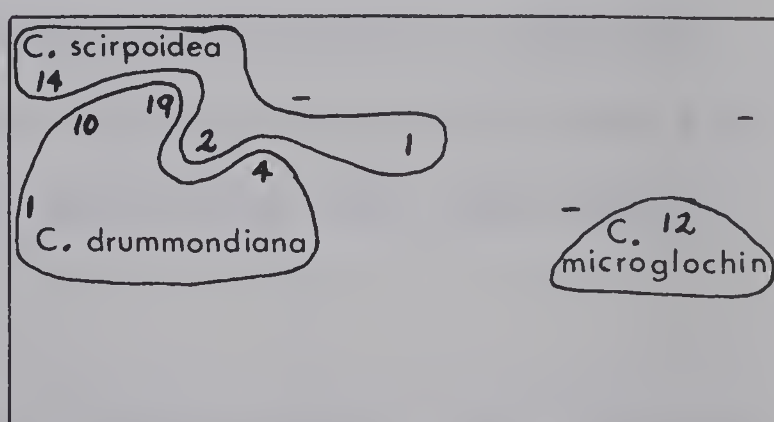


FIGURE 44.
CAREX SPECIES

The highest species diversity was found in the drier and earlier snow-free communities (Fig. 24), suggesting a higher total number of Chionophobes than Chionophiles. Vascular species, however, show split maximum diversity, with one peak in the more xeric (D) and the other in the more mesic (L) communities (Fig. 25), which is roughly coincident with Chionophobe (Fig. 26) and Chionophile (Fig. 27) prominence, respectively. Alpine Constants are maximal in communities with more intermediate conditions (Fig. 28) and minimal in communities with the highest proportion of Chionophiles.

When prominence distributions of individual species were plotted on ordination diagrams, no two species showed exactly the same pattern, i.e., niche requirements. Several examples are shown in Figs. 29-44.

Although *Dryas hookeriana* and *Silene acaulis*, both moderate Chionophobes, are found in the same community types, their respective maxima do not coincide: *Dryas* prominence values are highest where *Silene* is usually less prominent (Figs. 29, 30). The more extremely chionophobic *Oxytropis podocarpa* has a still different pattern (Fig. 31), with its maximum prominence where *Dryas* and *Silene* are high but not at their highest.

Two chionophilic species, *Veronica alpina* and *Erigeron peregrinus* (Figs. 39, 40), also demonstrate rather different prominence distributions, but at the other end of the snow

release gradient. *Veronica* has maximum prominence in community M whereas *Erigeron* achieves this in communities L and H. *Erigeron* may be more strongly influenced by the moisture gradient and/or requires a longer growing season than *Veronica*. *Veronica*, on the other hand, may encounter greater competition in communities H, J and K where taller forbs or graminoids are more prominent.

Salix, *Cassiope* and *Campanula* are three examples of genera with species that have overlapping distributional ranges on Signal Mountain (Figs. 33-38). *Salix arctica* and *S. nivalis* are both classed as Alpine Constants (Table 38), but whereas the former is most prominent in the more mesic communities the latter is most prominent in communities that are more xeric. The distribution of *Vaccinium vitis-idaea* is similar (Fig. 32) to that of *Salix nivalis*, and appears to be a function of the Y-axis (probably the moisture gradient); however, *Vaccinium* does not tolerate the most xeric portion of this gradient.

Campanula lasiocarpa is found in all communities except M, being most prominent in the moderately mesic communities H and L. Its relatively lower prominence in community J may be attributable to competition offered by the dense growth of the dominants, *Cassiope mertensiana* and *Phyllodoce glanduliflora*. *Campanula uniflora* is a Chionophobe that is found in the xeric portion of *C. lasiocarpa's* range. These two species also have different phenological patterns: *C.*

uniflora has a shorter and earlier flowering period (late June to mid-July in 1967), while *C. lasiocarpa* begins flowering toward the end of the blooming period of *C. uniflora* and continues to flower until autumn. Similar distribution and phenology are exhibited by *Potentilla diversifolia* an Alpine Constant, and the chionophobic *P. nivea*.

Cassiope tetragona and *C. mertensiana* are Chionophiles, with the latter being much more restricted than the former (Figs. 35, 36). Although both are found in one community (L), each is absent from the community in which the other is a dominant species.

Gentiana glauca and *G. prostrata* do not co-exist in any of the analyzed communities. Their respective distribtuions are probably determined by soil moisture: *G. glauca* occurs in more moist areas while *G. prostrata* is at more xeric sites. A few plants of *G. prostrata* were found in the very wet community (K) but only on the drier tops of hummocks.

Two *Antennaria* species occur in distinct groups of communities based on snow accumulation and release (Fig. 42). *A. alpina* is a Chionophobe that is tolerant of xeric sites while *A. lanata* is found in late snow-release areas. *Arnica alpina* and *A. latifolia* exhibit niche partition similar to that of the *Antennaria* species. *Arnica alpina* is present in communities A, B, C, D, E, and *A. latifolia*

in communities H, J, L and M.

Species of *Carex* probably offer the best examples of niche partition (Figs. 43, 44). Every community includes at least one species of *Carex*. *C. drummondiana* was recorded in four communities, the maximum number of occurrences. Several species, e.g., *C. microglochin* and *C. phaeocephala*, where recorded in only one community. Tolerance ranges of individual species of *Carex*, therefore, do not appear to be great and several environmental factors probably govern their distribution patterns.

Distributional Interrelations of Communities

Several areas on Signal Mountain afford the opportunity to observe concrete examples of ecological zonation exhibited by the community types described in preceding sections. These zonations vary greatly in scale, areal extent and completeness, depending on the rate and continuity of change in the environmental factors involved.

Vegetation-environment interaction is well demonstrated on large boulders on the S slope (Plate 29). Downslope faces, which are exposed to maximal insolation and wind, are relatively free of vegetation; only a few patches of lichens and cushion plants, such as *Potentilla nivea* and *Saxifraga bronchialis*, are established on slightly protected areas or in crevices. The upslope portions of such boulders, however, have a thick cover of vascular plants and bryophytes.

PLATE 29. An erratic boulder, about 10 m^3 in size, on the S slope of Signal Mountain. The downslope face, on the left, is facing S and W and is therefore exposed to much wind and maximal insolation. Vegetation is sparse, with a few lichens in more protected areas and cushion plants occasionally in crevices. The upslope and protected portion of the boulder, on the right, supports a well-developed cover of vegetation on a thin accumulation of soil.

(Photographed July 2, 1967).

The chief species appear to be grasses and sedges, such as those in the *Dryas* - graminoid community, with some *Dryas*, *Anemone drummondii*, *Stellaria monantha*, *Draba* species, and others.

Although a somewhat similar situation is found on boulders on the N slope, it is less pronounced as the amount of wind, moisture and temperature differences probably do not vary as greatly with aspect as they do on the S slope. However, there is some variation; it was noted that krummholz is occasionally present on the downslope (N or E) side of boulders but never on the upslope side.

The deposition, accumulation and duration of winter snow cover appear to be the chief environmental variables controlling the vegetation pattern. Evidence of the influence of snow was found on all slopes.

A small, trench-like depression which accumulates much snow was observed on the S slope during the 1967 study season. It provided some useful information on probable relationships between snow release dates and dominant species cover (Plates 30, 31). On June 4 areas with *Dryas*-dominated cover had been free of snow for some time while areas with *Cassiope tetragona* cover were just being released. By July 4 the latest patch of snow in the deepest portion of the depression was gone. From periodic observations between the two dates dominant species could be ranked according to snow release, from earliest to latest,

in the following order: *Dryas hookeriana, Cassiope tetragona, Antennaria lanata* and *Phyllodoce glanduliflora, P. empetriformis, Carex nigricans. Salix arctica* is present in all but the *Carex nigricans* patch. *Claytonia lanceolata, Arabis drummondii* and *Agoseris aurantiaca* were found in the lowermost portion of the *Antennaria*-dominated area, but were not present in the equivalent community on the N slope. The *Phyllodoce* species are less exposed to dessicating agents than is *Antennaria lanata* because the former occur only on the N-facing bank of the depression whereas the latter is on banks of all aspects. The same community types on the N slope were released from snow one to three weeks later.

The influence of snow is particularly evident on the N slope. From field observations it appeared that the order in which N slope communities are released from snow, from earliest to latest, is probably as follows: E (*Dryas* - moss), F (*Cassiope tetragona* - *Dryas*), H (*Dryas* - *Salix arctica*), J (*Cassiope mertensiana* - *Phyllodoce glanduliflora*), N (*Salix nivalis*), L (*Salix arctica* - *Antennaria lanata*), M (*Carex nigricans*), O (nivation hollows). The ordination diagram also supports this order (Fig. 16, p. 200). Most of these communities, except H, J, and N, are shown grading into each other in Plate 32, a pattern that is very common although all communities are not always represented within such relatively short distances from each other.

PLATE 30. A late snowpatch on the S slope of Signal mountain, photographed on June 4, 1967. All areas dominated by *Dryas hookeriana* were now free of snow and *Cassiope tetragona* patches were in the process of being released from snow.

The krummholz at the lower right is *Picea engelmannii*, the patch in the upper centre is *Abies lasiocarpa*. The view is to the NE.

PLATE 31. The same view as above on July 1, 1967. Areas which were under snow near the periphery of the snowpatch above now show a dominantly *Antennaria lanata* cover (greyer than the *Dryas*-dominated vegetation). A transitional zone in which both *Dryas* and *Antennaria* are found varies in width, being widest on the left hand (S-facing) bank of the depression. *Phyllodoce* species occupy smaller areas than does *Antennaria*, on the right hand (N-facing) bank of the trench at centre right, with *P. glanduliflora* growing above *P. empetriformis*. The deepest portion of the depression has brownish *Carex nigricans* which has been very recently released from snow. Only a very small snowpatch is still present at the deepest point in the depression.

PLATE 32. Vegetation zonation near the top of the North Draw on the N slope of Signal Mountain. The areas of latest snow release are nivation hollows on the upslope banks in the upper centre to left. The second latest is the *Carex nigricans* patch (yellow-brown) at the left centre, surrounded by the earlier *Salix arctica* - *Antennaria lanata* (grey with yellow flowers of *Castilleja occidentalis*). This in turn is surrounded at the right by the still earlier *Cassiope tetragona* (dark green). The earliest community to be released from snow is the *Dryas* - moss (brownish green) in the elevated area at the upper middle right.

(Photographed August 18, 1969).

The effects of winter snow accumulation are both direct and indirect (Billings and Bliss 1959, Bliss 1962). While plants beneath are protected from severe winter conditions, their growing season is late and short. The proximity of snowpatches will reduce both soil and air temperatures, but an adequate water supply is generally available to the vegetation nearby and below.

Two other N slope communities, G (*Dryas - Empetrum*) and K (*Salix arctica - Arctagrostis*), may not fit directly into the snow release gradient, and snow release dates of these unfortunately were not noted. In these two community types an abundance of water during at least part of the summer appears to be a major control. Community K, in particular, has a high cover of vegetation including many species not found in other community types (see Table 38).

Plant communities associated with solifluction terraces (H and J) are indirectly influenced by water abundance as this is the causal agent for solifluction. The vegetation of stone polygons and nets was not analyzed but probably could also be included with the snow and water controlled communities.

Topography has a very important, though indirect, influence on vegetation patterns because of its effects on snow accumulation, the channelling of water, and on air movements. Variations in slope aspect and angle appear to be far more effectual on distribution patterns than are

elevational differences, which are no greater than 250 m in Signal Mountain's alpine zone.

Because water moves in depressed or eroded channels, vegetational changes at the edges of stream beds can be quite abrupt (see Plate 24, p. 166). Thus the most xerophytic community type (E: *Dryas* - moss) of the N slope may border such stream beds if the slope angle is sufficiently great.

Wind has not only a direct abrasional effect in the alpine zone, it has an indirect effect on the vegetation through its influence on snow cover and the moisture regime (Bliss 1962). Although summer winds are not generally of great import on the N slope, areas of greater exposure to wind are covered by the *Dryas* - moss community type (E) which has several species commonly associated with S slope communities, e.g., *Selaginella densa* and *Campanula uniflora*.

Wind is a much more important factor on the S slope and ridge top areas which are exposed to prevailing wind directions. Rocky communities of cliff and scree are exposed to maximal wind as well as the highest temperatures due to more direct insolation and the presence of open rock. The degree of dessication to which these areas are subjected is reflected in the predominating growth forms. Vegetation of rock crevices and the uppermost scree and fellfield areas consists chiefly of cushion plants. Mat-forming species dominate at somewhat lower elevations, and

graminoids and single-growing species increase with a further decrease in elevation. In this the S slope vegetation differs from that of the N slope communities where elevational differences within the alpine zone appear to have little, if any, direct influence.

An interesting and possibly important phenomenon was noted several days after a severe summer snowstorm on Signal Mountain in early July, 1968. A NE wind, which is usually associated with this type of storm, was effective in depositing heavy drifts of snow on the S (lee) slope. The extensive snowpatches were located below the cushion plant area of the scree slopes and fellfield, on the uppermost portion of the area supporting *Dryas* islands and stripes (Plate 33). Such storms may be of sufficiently frequent occurrence to provide the moisture requirements of species that would otherwise be unable to withstand the seemingly xeric conditions during the growing season.

The *Dryas* - graminoid community (B) receives comparatively less wind and more moisture than the other S slope communities. Because of this, it is more like the N slope communities than are other communities of the S slope, and species that are generally more abundant on the N slope are more prominent in community B than in other S slope communities, e.g., *Salix arctica, Carex petricosa, Artemisia norvegica* and *Potentilla diversifolia* (see Table 38).

PLATE 33. The S slope of the main ridge of Signal Mountain, three sunny days after a summer snowstorm, showing the pattern of snowdrifts resulting from the accompanying NE wind. Only the oval-shaped snowpatch near the bottom of the photograph is a remnant of winter snow.

(Photographed July 3, 1968).

The saddle area between the True Summit and the East Knob (see maps in Figs. 2, 3, pp. 7, 9) has topographic protection from prevailing westerly winds but upslope winds are probably funnelled through it. The lowest portion of the saddle is dominated by *Dryas*, with *Silene acaulis* and *Myosotis alpestris* also prominent. *Cassiope tetragona* is the dominant species in upslope areas on the two sides of the saddle where snow release is earlier than in the saddle base where *Dryas* is dominant. The development of the *Dryas*-dominated community type may, therefore, be controlled more by a moisture deficit during mid- and late summer than by the amount of snow accumulation earlier in the year. However, further observations, especially following winters of low snowfall and accumulation, are required.

It has already been pointed out that *Dryas hookeriana* dominates almost all plant communities on the S, W and E slopes of Signal Mountain. Although N slope vegetation may be described as a mosaic of community types, *Dryas*-dominated communities (E, F, G and H) cover a substantially greater total area than do those lacking *Dryas*. This is demonstrated by the vegetation profile of the transect discussed in the next section.

The overall dominance by *Dryas* of Signal's alpine zone is probably related to the location of the mountain at the N end of the Maligne Range (see Fig. 1, p. 3). This location exposes Signal to a large amount of wind which is

funnelled down the broad Athabasca River valley as well as the many subsidiary valleys, the most important being the Miette River valley which extends eastward from Yellowhead Pass on the Great Divide directly toward Signal Mountain. Summer winds have a dessicating effect on vegetation and the substrate, while winter winds are responsible jointly with topographic unevennesses for snow accumulation patterns.

From 1967 field observations it appeared that Signal received less precipitation than the surrounding area, but during the wetter summers of 1968 and 1969 this did not seem to be the case. Nevertheless, the somewhat low annual precipitation (normal of 40.6 cm or 16.0 inches) in the Jasper townsite area and the presence of mountains higher than Signal in the immediate vicinity contribute to a relatively dry climate on Signal Mountain.

Mountain Transect

To simplify presentation of data obtained from the transect crossing the main ridge of Signal Mountain (Fig. 45, see also Fig. 3, p. 9), it was decided to group cover point data from ten 25 cm quadrats analyzed at 1 m intervals and cover estimate data at 10 m intervals to show presence of selected species and the communities represented within each such 10 m interval. Although the 10 m distance was often too great to show variations on a microenvironmental scale, several points, including some discussed in earlier sections, are fairly well demonstrated by the method used. Only one

community, the very wet *Salix arctica - Arctagrostis* - moss (K), was not encountered on the transect.

Tree line, as defined earlier (p. 12), is somewhat higher (by 24 m) on the S slope than on the N slope. Although the highest occurrence of prostrate (infranival) krummholz was noted on the S slope (elev. about 2140 m), this was not noted on the N slope because such krummholz was some distance from the transect.

The preponderance of *Dryas* cover in the alpine zone is shown by the record of this species in 82% of the 10 m intervals. *Campanula lasiocarpa* has the second highest record with 76% and *Salix nivalis* third with 66% of the intervals having the respective species recorded. Two other Alpine Constants, *Polygonum viviparum* and *Salix arctica*, were recorded in 56% of the intervals. Although *Artemisia norvegica* was recorded in all the quantitatively analyzed community types it was recorded in only 53% of the transect intervals. The rarer occurrence of both *Artemisia* and *Salix arctica* in S slope and ridge top areas is thus emphasized.

Most cushion plants were recorded only on the S slope and ridge tops where drier conditions prevail. However, *Silene acaulis* was found throughout the transect, although it is more prominent in S slope and ridge top areas. *Saxifraga oppositifolia* appears to be a good indicator of ridge-top conditions and is present even on the smaller

ridge on the N slope which receives more protection than the main ridge. Several typically S slope species, *viz.*, *Selaginella densa, Campanula uniflora, Potentilla nivea* and *Oxytropis podocarpa*, were also recorded on this small ridge.

Potentilla nivea, an ubiquitous cushion plant on the S slope, was recorded in all but the lowermost 10 m interval of the southern portion of the transect.

Although the cushion growth form has a pronounced association with the S slope and ridge tops, the other three growth forms are prevalent on both N and S slopes. There is, however, a greater diversity of mat-forming species on the N slope.

There was no 10 m interval on the N slope without at least one mat-forming species recorded, and in only 10% of these were no dwarf shrubs recorded; *Dryas* and *Salix arctica* appear equally abundant with each recorded in 80% of the intervals. However, a single-growing species, *Campanula lasiocarpa*, had the highest record of 84% of the N slope intervals (55% on the S slope); third highest was *Artemisia* recorded in 68% and fourth was *Sibbaldia* in 64% of the N slope intervals.

Heather species were recorded only on the N slope where the greater abundance of *Cassiope tetragona* was demonstrated. Whereas *C. tetragona* was recorded in 62% of the N slope intervals, *C. mertensiana* was recorded in 28% and *Phyllodoce*

species in 30%.

Oxyria digyna is another good indicator of sharply defined conditions, being recorded only in the nivation hollow located in the North Draw. The few other species recorded here are all typically N slope species. The zonation of community types, as shown in Plate 32 (p. 216) shows particularly well in this region, between 330 and 430 m of the transect distance.

The presence of many boulders of varying sizes as well as a considerable amount of solifluction have both contributed to a very uneven topography at the northern end of the transect (from 550 to 790 m). This has resulted in the creation of small scale microenvironmental variations that are shown by the number of community types represented in each 10 m interval. In many of these, the communities would be classed as transitional community types.

Some of the lowermost species shown in the transect diagram, i.e., *Arctostaphylos uva-ursi* and *Zygadenus elegans* on the S slope, and *Empetrum nigrum* on the N slope, may be at the uppermost limits of their distribution.

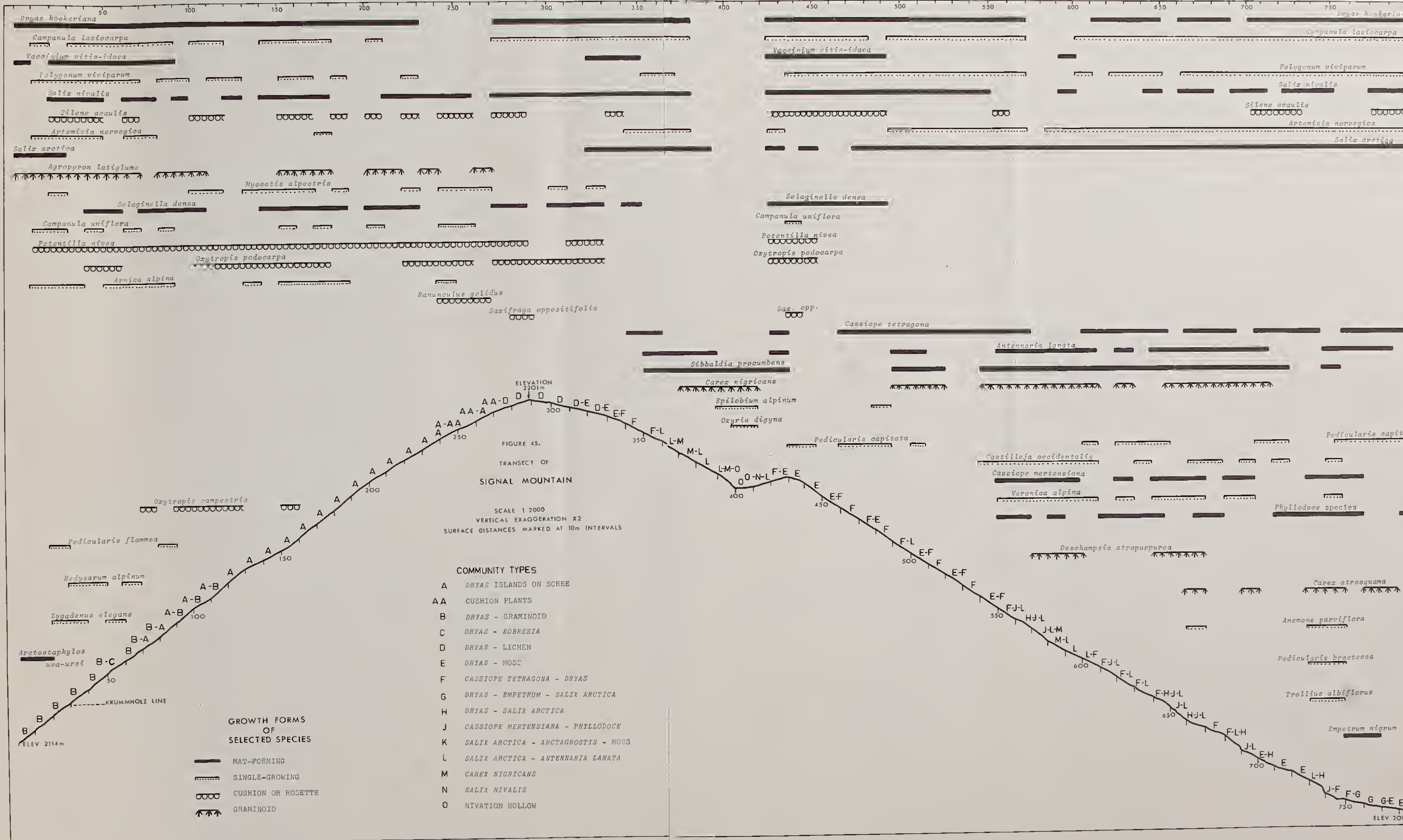


FIGURE 45.
TRANSECT OF
SIGNAL MOUNTAIN
SCALE 1:2000
VERTICAL EXAGGERATION X2
SURFACE DISTANCES MARKED AT 10m INTERVALS

BRIEF COMPARISON OF SIGNAL MOUNTAIN FLORA WITH THAT OF RELATED AREAS

Comparisons of plant communities with those described by other authors is difficult because each researcher has a somewhat different set of criteria in delimiting plant communities and analyzing the vegetation. For example, Beder (1967), in the only other ecological study of alpine communities in the Far Northern Rockies, considered the *Carex nigricans* and *Salix arctica - Antennaria lanata* communities as one association in Snow Creek valley, whereas in the Signal Mountain study they were treated as two separate community types. This may be a case of where one decides to draw the lines on the continua of vegetation-environment interactions. It is possible, however, that the later portion of the snow release gradient is not so steep at the more southerly latitude and the two community types may not segregate so clearly as they do on Signal. At the other end of the scale, perhaps finer differences may appear in the Rocky Mountains at more northerly latitudes, but, unfortunately, at present such data are lacking. It was decided, therefore, to compare related alpine and arctic areas in North America with that of Signal Mountain on a floristic rather than a synecological basis.

Beder has shown that the Snow Creek valley study area in Banff National Park has a far richer species diversity than Signal Mountain. The comparisons of plant groups,

Snow Creek : Signal Mountain, are as follows - vascular plants 285:157, bryophytes 84:87, and lichens 100:53. Some of the reasons for this difference may be environmental, such as more mesic conditions, the more southerly latitude, or the calcareous substrate compared with Signal's highly siliceous and acid one. Another reason may be a less stringent definition of the alpine zone since areas with scattered islands of trees were included in the Snow Creek area, whereas these were treated as the upper subalpine zone on Signal.

A strong arctic influence is seen in the alpine flora of Signal Mountain. Two important species, *Arctagrostis arundinacea*, which is a co-dominant in the very wet area, and *Campanula lasiocarpa*, an ubiquitous Alpine Constant, are both Beringian arctic species; they have not been reported at Snow Creek nor in the Rocky Mountain areas to the south. A similar situation is found with the following circumpolar arctic and boreal species found on Signal: *Ranunculus nivalis, Potentilla hyparctica, Pyrola grandiflora, Arctostaphylos rubra, Vaccinium vitis-idaea, Pedicularis lanata* and *P. flammea*. Further intensive study is necessary to substantiate the southern limits of these species.

Other arctic species common on Signal which appear to be restricted to the Far Northern Rockies and adjacent mountains in British Columbia are *Cardamine bellidifolia, Equisetum scirpoides, Gentiana glauca* and *G. propinqua*.

Two other arctic species, *Papaver kluanensis* and *Erysimum pallasii*, were expected but not found on Signal. Both are present on The Whistlers, a mountain across the Athabasca River valley from Signal and similar geologically and in its climate. The only immediately apparent reason for their absence is elevational, as Signal's highest point is 2311 m and these species are found from about 2345 to 2460 m on The Whistlers.

Several vascular species found by Beder in Banff Park but not found on Signal are more common in the more southern regions, *viz.*, Northern and Central Rockies. Some of these are *Larix lyallii*, several *Poa species*, *Stenanthium occidentale*, *Eriogonum androsaceum*, *E. subalpinum*, *Claytonia megarrhiza*, *Delphinium bicolor*, *Ranunculus glaberimus*, *Sedum rosea*, *Polemonium pulcherrimum* and *Townsendia parryi*.

Signal species common in the alpine zone of the Northern and Far Northern Rockies that do not occur in the Central Rockies are in two groups, those classed as arctic-alpine and others that are Cordilleran in range. The former group includes *Salix vestita*, *Anemone parviflora* and *Saxifraga oppositifolia*, while the latter includes *Anemone drummondii*, *Antennaria lanata*, *Draba incerta*, *Phyllodoce glanduliflora* and *Cassiope mertensiana*. Another species, *Cassiope tetragona*, occurs in the arctic but the subspecies *saximontana* is Cordilleran. The importance of this species appears to diminish southward. Although pure stands of it

cover extensive areas in the arctic (Porsild 1951), stands on Signal include a considerable proportion of *Dryas hookeriana*. In Montana, Bamberg (1961) and Choate (1963) reported the occurrence of only small scattered patches. *Dryas hookeriana* is also reported by these authors as being a dominant species in the Northern Rockies, as it is on Signal. Although present in the Colorado mountains, *Dryas* appears to have much less prominence there. Some important species in the Central Rockies (Griggs 1956, Holway and Ward 1965, Johnston and Billings 1962) are *Paronychia pulvinata, Geum turbinatum, Geum rossii, Trifolium dasyphyllum, T. nanum* and *Phlox caespitosa*, none of which occur in Alberta.

Some of the arctic-alpine species which occur throughout the range from the Arctic Archipelago (Porsild 1964) to the Central Rockies, including Signal Mountain, are *Poa alpina, Deschampsia caespitosa, Festuca brachyphylla, Carex drummondiana (= C. rupestris), C. scirpoidea, Kobresia bellardii, Juncus drummondii, Oxyria digyna, Polygonum viviparum, Arenaria sajanensis, Silene acaulis, Draba crassifolia, Ranunculus pygmaeus, Saxifraga cernua, Sibbaldia procumbens, Oxytropis podocarpa, Campanula uniflora, Crepis nana, Erigeron compositus* and *Solidago multiradiata*.

Cordilleran species common on Signal, whose ranges include Alaska and Yukon to the Central and Southern Rockies,

are *Carex nigricans*, *Ranunculus eschscholtzii*, *Saxifraga bronchialis*, *Phyllodoce empetriformis*, *Veronica alpina*, *Erigeron peregrinus*, *Saussurea densa*, *Senecio triangularis* and *S. cymbalarioides*. Several Cordilleran species, which are found in the Central to Far Northern Rockies but do not occur in Yukon or Alaska, are probably approaching the northern limits of their ranges in their occurrence on Signal Mountain. The more important of these are *Salix nivalis*, *Claytonia lanceolata*, *Gentiana prostrata*, *Vaccinium scoparium*, *Potentilla diversifolia* and *Dryas hookeriana*.

Bryophytes and lichens appear to become more important northward. Although relatively low in cover and species diversity in the Central and Northern Rockies alpine areas, they are far more abundant in the Far Northern Rockies. The lichens, in particular, reach maximum importance in arctic areas.

In earlier sections of this thesis vegetational gradients were discussed on a microenvironmental to a regional basis on Signal Mountain. From the discussion in this section it may be seen that these vegetational gradients extend to the broader continental basis.

SUMMARY

1. The objectives of this study were to describe, quantitatively and qualitatively, the major plant communities and some of the environmental factors influencing their development and distribution in the alpine zone of Signal Mountain.

2. The bedrock of Signal is Precambrian in age and consists of resistant arenaceous strata interbedded with lenses of less resistant argillaceous rocks. Pleistocene glaciation has given the mountain a relatively smooth macrotopography, but differential weathering and forces exerted by frost action and gravity have contributed to a highly variable microtopography. The topographic variations have contributed directly and indirectly to vegetational distribution patterns.

3. The alpine zone is vegetationally defined as the zone in which tree species can no longer maintain upright, supranival flagging. Although the zone of continuous forest is much lower, tree line, which marks the uppermost limit of the subalpine zone, is at 2115 m on the S slope and 2090 m on the N slope. Krummholz, however, occurs at higher elevations on the N slope, up to 2250 m compared with 2190 on the S slope.

4. Temperatures at several levels above and below the ground surface, solar radiation and relative humidity were recorded at the major meteorological station located at an elevation of 2200 m. Where possible, observations were compared with those at valley stations, at Jasper townsite

and Devona Warden Station. Maximum temperatures were found to be consistently lower on Signal than in the Athabasca River valley. However, minimum temperatures were usually lower in the valley during generally warmer periods and higher than on Signal during cooler periods of unstable weather. Of the levels measured on Signal, the temperature range was greatest at 18 cm above ground. The ground had a decided moderating influence on minimum temperatures at 2 cm depth and on both the maxima and minima at 10 cm depth. Solar radiation ranged from 198 to 837 ly/day, with a mean of 33 ly/daylight-hr during the 70-day study period in 1967. Relative humidity ranged from 20 to 100%. The V.P.D. for the warmest day of the season was calculated at 22 mb.

5. Precipitation and wind mileage readings were made at the fire lookout located at 2137 m. Precipitation was probably normal during June and July, but was much lower in August. The heavier than normal snowfall during the preceding winter probably offset, at least partly, the general lack of precipitation in August, as snowbanks were melting until late August. A small snowbank glacier contributes meltwater to the areas below it throughout the warmer seasons. Wind was almost always present. Prevailing winds are from the W to SW, with strong reinforcement by upslope winds on the S and SW slopes. The highest wind velocities were recorded during the afternoons and early evenings of very warm days. Summer snow storms appeared to be associated with NE winds.

6. Microenvironmental observations at 8 stations consisted of maximum and minimum air temperatures and spot readings of soil temperature and wind velocity. Comparisons were made with the respective continuous records at the major station as well as with each other. Air temperatures at S slope sites were higher, especially the maxima, than at N slope sites, with the highest recorded at the S scree station and the lowest at the very wet station on the N slope. Soil temperatures showed a direct correlation with air temperatures and with soil moisture content. Soil temperatures under vegetation were consistently lower than under bare ground. Wind velocity readings were higher at S slope stations and lowest at protected N slope stations. Elevational differences did not appear to be correlated with differences in any of the measured environmental factors.

7. The alpine soils on Signal are mostly shallow, poorly developed and very coarse in texture. Soil depth averaged 36 cm and slightly exceeded 50 cm in only 2 of the 23 profiles examined. Maximum root penetration ranged from 17 to 40 cm. Roots were found at depth under bare ground in all such profiles examined. Texturally, sandy loams predominate, with the ratio of gravel + sand/fines greater than 1 in all the S slope, ridge top and some of the N slope soils, and equal to or slightly less than 1 only in the most mesic areas. Available moisture values ranged from 4% to 22% in S slope soils and 10% to 53% in N slope soils. The best horizon development appeared to be

associated with more mesic conditions. Soil reaction ranged from slightly to strongly acid (pH 6.5 to pH 4.5). Nitrate and phosphate contents were generally low but potassium content was very variable, with highest values in soils from the more mesophytic communities. The properties of all soils are compared in one table.

8. Of the 157 vascular species identified on Signal, about 30% have a Cordilleran distribution and 45% an arctic-alpine distribution, thereby indicating the strong boreal influence at this latitude of almost 53°.

9. Compact growth forms, including mats, tussocks, cushions and rosettes, predominate. Dwarf shrubs are dominant and half of these species are evergreen. *Dryas hookeriana* and *Salix arctica* are the most abundant dwarf shrubs and either or both dominate most communities on all slopes. Cushion and rosette-forming forbs are much more prevalent on the S slope and ridge top. The single-growth form is most prominent in mesic and somewhat unstable habitats. All but 3 species of the alpine flora are perennial.

10. Fifteen stands, representing 12 community types, were sampled quantitatively for cover and frequency data. Three more were qualitatively analyzed. Indices of Similarity between quantitatively analyzed communities were calculated using Prominence Values ($C \times \sqrt{F}$) of 94 species. A matrix of the I_{sim} values shows an almost linear relationship between communities. The 15 communities are described in

the order of highest similarity with each other.

11. *Dryas* islands on scree (A) occur on the relatively steeper S slope, with vegetation stripes forming where the slope angle lessens. A more continuous vegetation cover develops with decreasing slope angle and elevation. This is a xerophytic and highly chionophobous community having maximal insolation, high winds, high temperatures, and very coarse, well-drained soils. Although the vegetation cover is low on scree, species diversity, especially in lichens, is comparatively high.

12. Cushion plant communities of rock crevices (AA) are found on S-facing cliffs. The vegetation is extremely xerophytic and chionophobous, and probably tolerates the most severe environmental conditions on the mountain. Species diversity is quite low and, unlike the other xerophytic communities, *Dryas* is rare.

13. The *Dryas*-graminoid community (B) occurs on patterned ground on the S slope. It is somewhat more mesophytic than the communities above due to some topographic protection from horizontal winds and a greater amount of moisture seeping down from the saddle area. It is moderately chionophobous, the soil is coarse and poorly developed, lichen prominence is low, but bryophytes are more prominent than in other S slope community types.

14. The *Dryas* - *Kobresia* community (C) on the very windy

and consequently xeric SW slope is extremely chionophobous. The soil is coarse in texture but there is a better developed profile and a higher vegetation cover than in other S slope community types, thus suggesting greater stability.

15. The *Dryas* - lichen fellfield community (D) on the ridge summit is xerophytic and highly chionophobous in general. The presence of some protected microtopography in which more mesophytic elements can exist contributes to the highest species diversity found in the alpine communities. The soil mantle is very variable, but is mostly very thin and coarse with many unvegetated areas.

16. The *Dryas* - moss community (E) is the most common on the N slope and a very variable community type. It is found on uneven, hummocky areas having the greatest exposure on the N slope. Though more mesophytic than S slope communities, thus having a great reduction in compact forb prominence, this is the most xerophytic and chionophobous of N slope communities. Similarly, the soils are less coarse than those of S slope communities but are better drained than others on the N slope. *Salix arctica* and moss prominence increase with greater water supply from melting snowbanks above. Because *Cassiope tetragona* occurs in depressional areas, this community type grades into the next one.

17. The *Cassiope tetragona* - *Dryas* community (F) is in slightly depressed and/or protected sites and is also very common on the N slope. It is moderately chionophilous and

mesophytic. The tussocky growth of *Cassiope* and a relatively higher moisture supply both contribute to the uneven microtopography. The soils are not quite so coarse as in the *Dryas* - moss community.

18. The *Dryas* - *Empetrum* - *Salix arctica* community (G) is found in areas of "pancake terraces" where solifluction forms garland patterns on the N slope. Snow release dates were not noted, but moisture is apparently adequate for slumpage. Open gravel areas resulting from frost action occupy the terracette tops and are underlain by coarser soils than are the vegetated areas. Soils under the vegetation here had the highest clay content of all Signal alpine soils. The vegetation could be classed as two microcommunity types, with *Empetrum* dominant on the terracette risers and *Dryas* on the areas between. Species diversity is high, especially in graminoids and bryophytes.

19. The *Dryas* - *Salix arctica* community (H) on solifluction terrace risers on the N slope is a mesophytic community type that is probably released from snow later than the previous one. The physical instability of solifluction lobes probably contributes to the preponderance of tall single-growing forbs and low lichen diversity. This is the last of the described community types in which *Dryas* and *Silene acaulis* occur. Very wet solifluction terraces lack *Dryas* and graminoids are more prominent.

20. The *Cassiope mertensiana - Phyllodoce glanduliflora* community (J) at solifluction terrace bases is a highly chionophobous and mesophytic community type. The soils are finer in texture and better developed than in previous community types described and there is evidence of some gleization. The vegetation has a lush appearance, single-growing and graminoid species diversity is high, but lichen diversity and cover are low. Though not a dominant species, *Salix arctica* has high prominence.

21. The *Salix arctica - Arctagrostis* - moss community (K) is found in the very wet area at the seepage spring below the snowbank glacier on the N slope. Large hummocks and stone nets have formed. The date of snow release was not recorded. Many of the vascular species are rooted in *Sphagnum warnstorfianum* and other mosses, together with their remains, in the top 10 cm of the substrate. The mineral soil below that depth has the finest texture of all Signal soils and gleization is pronounced. Vascular and lichen species diversity is low but bryophyte diversity is high. Graminoids are more prominent than the other vascular growth forms. A considerable number of species present here were not found in any other described community.

22. The *Salix arctica - Antennaria lanata* community (L) is extremely chionophilous, moderately to highly mesophytic, and fairly common on the N slope. It is present but uncommon and covers only small areas on the S slope. The general

topography is depressional with small hummocks. Soils are fine in texture with obvious stirring by frost under hummocks. All three plant groups are prominent, with lichens more abundant than in any other community type. Vascular species diversity is high, with good representation by all growth forms. *Erigeron peregrinus* and *Castilleja occidentalis* tend to be aspect dominants during periods of peak anthesis.

23. The *Carex nigricans* community (M) is an extremely chionophilous one which occupies areas of latest snow release where a continuous cover of vegetation exists. It is very common on the N slope but also occurs in deeper depressions on the S slope. The soils are relatively deep and fine-textured, with some mottling and mixing by frost action. Floristically, it is very distinct from other community types, with the mean I_{sim} = 1.1%, and has the lowest species diversity in each of the plant groups.

24. The *Salix nivalis* community (N) forms small carpets in late snow-release areas although this dwarf shrub is also common in dry chionophobous communities such as those on scree. The qualitatively examined stand is in a trench which appeared to have deposits of fine wind- and possibly water-transported soil particles. The associated species are chiefly chionophilous.

25. Nivation hollows (O) which have a snow cover lasting up to 10 or 11 months of the year have very sparse vegetation due to both the short growing season and physical factors.

Comparatively few species were observed here, and most probably would not reach sufficient maturity to produce seed.

26. Interrelationships and floristic comparisons of the alpine plant communities are shown by the arrangement of most of the species in a phytosociological table. Three main groupings emerge: (1) Chionophobes, which have relatively narrow tolerance ranges, (2) Chionophiles, which also have narrow tolerance ranges, and (3) Alpine Constants, which have wide ecological amplitudes.

27. A two-dimensional ordination based on Indices of Dissimilarity was constructed. Vegetational relationships between communities are shown by the ordination patterns of 3 major species: (1) *Dryas hookeriana*, a Chionophobe, (2) *Salix arctica*, an Alpine Constant, and (3) *Carex nigricans*, a Chionophile. Environmental gradients appear strongly on the vegetational ordination: the nature of the topography and snow accumulation and release are aligned with the X-axis, and gradients of air and soil temperature, soil texture and available moisture are aligned with the Y-axis. Several vegetation variables are plotted on ordination diagrams to show their relationships with the environmental gradients, including dwarf shrub, forb and bryophyte prominence, total and vascular species diversity, and % Chionophobes, Chionophiles and Alpine Constants. The presence and prominence values of 23 selected species are

also plotted on ordination diagrams to show various patterns of niche requirements and partition.

28. Concrete examples of ecological zonation are present on Signal, ranging in size from large boulders to sections of the mountain. The location, orientation and geology of Signal determine the climate, topography, soil accumulation and development, wind effect, snow and meltwater patterns, moisture availability and substrate instability, all of which interact with the vegetation to produce patterns of community distribution.

29. A transect crossing the main ridge of Signal was surveyed and the vegetation analyzed along it. The data are presented with a scale model of the cross-section of the mountain. Presence of 39 individual species and all but one community type are shown for each 10 m interval of the transect. These data show the presence of *Dryas* in 82% of the 10 m intervals, *Campanula lasiocarpa* in 76%, *Salix nivalis* in 66%, *Salix arctica* and *Polygonum viviparum* in 56%. Growth forms are also shown: mat-forming species are present along the entire transect but cushions-rosettes are on the ridge tops and S slope. Heather species were recorded only on the N slope, with *Cassiope tetragona* the most prevalent of these. Vegetational zonation shows well in the area of the North Draw. Uneven topography, resulting in small scale microenvironmental variations, on a portion of the N slope has produced transitional community types along this part of the transect.

30. The alpine flora of Signal Mountain is briefly compared with that of arctic and other alpine areas in the Rocky Mountains. Distributional ranges for some of the more common species are given. A strong boreal influence is seen in the flora of Signal when compared with study areas in Banff Park, Montana and Colorado.

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APPENDIX I. LIST OF SPECIES FOUND IN THE ALPINE TUNDRA OF SIGNAL MOUNTAIN.

LICHENS
ASCOMYCETIDAE
LECANORALES

PANNARIACEAE

Psoroma hypnorum (Vahl) S. Gray

PELTIGERACEAE

Nephroma expallidum (Nyl.) Nyl.
Peltigera aphthosa (L.) Willd.
P. aphthosa var. *leucophlebia* Nyl.
P. canina (L.) Willd.
P. canina var. *rufescens* (Weis.) Mudd
P. lepidophora (Nyl.) Vain.
P. malacea (Ach.) Funck
Peltigera sp.
Solorina bispora Nyl.
S. crocea (L.) Ach.
S. octospora Arn.

STICTACEAE

Lobaria linita (Ach.) Rabenh.

CLADONIACEAE

Cladonia arbuscula ssp. *berengeriana* Ahti
C. cariosa (Ach.) Spreng.
C. chlorophaea (Flörke) Spreng.
C. ecmocyna (Ach.) Nyl.
C. gracilis (L.) Willd.
C. gracilis var. *chordalis* (Flörke) Schaer.
C. mitis Sandst.
C. pocillum (Ach.) O. Rich.
C. pyxidata (L.) Hoffm.
Cladonia sp.

LECIDEACEAE

Rhizocarpon geographicum (L.) DC.

STEREOCAULACEAE

Stereocaulon alpinum Laur.

UMBILICARIACEAE

Omphalodiscus krascheninnikovii (Sav.) Schol.
Umbilicaria hyperborea (Ach.) Hoffm.

APPENDIX I (cont'd.)

LECANORACEAE

Candelariella aurella (Hoffm.) Zahlbr.
Lecanora epibryon (Ach.) Ach.
L. polytropa (Ehrh.) Rabenh.
L. verrucosa Ach.
Ochrolechia uppsaliensis (L.) Mass.

PARMELIACEAE

Cetraria cucullata (Bell.) Ach.
C. ericetorum Opiz
C. islandica (L.) Ach.
C. nivalis (L.) Ach.
C. tilesii Ach.
Hypogymnia intestiniformis (Vill.) Räs.
Parmelia sulcata Tayl.

USNEACEAE

Alectoria nitidula (Th. Fr.) Vain.
A. ochroleuca (Hoffm.) Mass.
A. pubescens (L.) Howe
A. tenuis Dahl
A. vexillifera Nyl.
Cornicularia aculeata (Schreb.) Ach.
Dactylina arctica (Hook.) Nyl.
D. ramulosa (Hook.) Tuck.
Thamnolia subuliformis (Ehrh.) W. Culb.

PHYSCIACEAE

Physcia muscigena (Ach.) Nyl.
Rinodina mniaraea (Ach.) Körb.
R. turfacea (Wahlenb.) Körb.

TELOSCHISTACEAE

Caloplaca jungermanniae (Vahl) Th. Fr.
C. stillicidiorum (Vahl) Lynge

APPENDIX I. (cont'd.)

BRYOPHYTA
 SPHAGNA
  SPHAGNALES

SPHAGNACEAE

Sphagnum warnstorfianum Du Rietz

MUSCI
 DICRANALES

DITRICHACEAE

Ceratodon purpureus Brid.
Distichium capillaceum (Hedw.) B.S.G.
Ditrichium flexicaule (Swaegr.) Hamp.

DICRANACEAE

Dicranum bonjeanii De Not. ex Lisa
D. fuscescens Turn.
Paraleucobryum enerve (Thed. ex C.J. Hartm.) Loesk

POTTIALES

ENCALYPTACEAE

Encalypta rhaptocarpa Schwaerg.
Encalypta sp.

POTTIACEAE

Bryoerythrophyllum recurvirostre (Hedw.) Chen
Tortella fragilis (Hook. ex Drumm.) Limpr.
T. tortuosa (Hedw.) Limpr.
Tortula norvegica (Web.) Wahlenb. ex Lindb.
T. ruralis (Hedw.) Gaertn., Meyer & Scherb.

GRIMMIALES

GRIMMIACEAE

Grimmia alpicola Hedw.
G. apocarpa Hedw.
Grimmia sp.
Rhacomitrium canescens (Hedw.) Brid.
R. lanuginosum (Hedw.) Brid.

APPENDIX I. (cont'd.)

EUBRYALES

BRYACEAE

Bryum creberrimum Tayl.
B. pseudotriquetrum (Hedw.) Gaertn., Meyer & Scherb.
B. stenotrichum C. Müll
Bryum sp.
Pohlia cruda (Hedw.) Lindb.
P. nutans (Hedw.) Lindb.

MNIACEAE

Mnium orthorrhynchum Brid.

AULACOMNIACEAE

Aulacomnium palustre (Hedw.) Schwaegr.
A. turgidum (Wahlenb.) Schwaegr.

MEESIACEAE

Meesia uliginosa Hedw.

BARTRAMIACEAE

Philonotis fontana (Hedw.) Brid.

ISOBRYALES

ORTHOTRICHACEAE

Orthotrichum sp.

HYPNOBRYALES

LESKEACEAE

Lescuraea incurvata (Hedw.) Lawt.

THUIDACEAE

Abietinella abietina (Hedw.) Fleisch.

AMBLYSTEGIACEAE

Calliergon giganteum (Schimp.) Kindb.
C. sarmentosum (Wahlenb.) Kindb.
Campylium polygamum (B.S.G.) C. Jens.
C. stellatum (Schimp.) Kindb.

APPENDIX I. (cont'd.)

Drepanocladus uncinatus (Hedw.) Warnst.
D. vernicosus (Lindb. ex C. Hartm.) Warnst.

BRACHYTHECIACEAE

Brachythecium salebrosum (Web. & Mohr.) B.S.G.
B. turgidum (Hartm.) Kindb.
Tomenthypnum nitens (Hedw.) Loesk

HYPNACEAE

Hypnum procerrimum Mol.
H. revolutum (Mitt.) Lindb.

RHYTIDIACEAE

Rhytidium rugosum (Hedw.) Kindb.

HYLOCOMIACEAE

Hylocomium splendens (Hedw.) B.S.G.

POLYTRICHALES

POLYTRICHACEAE

Pogonatum alpinum (Hedw.) Röhl.
Polytrichum juniperinum Hedw.
P. juniperinum var. *gracilius* Wahlenb.
P. norvegicum Hedw.
P. piliferum

HEPATICAE
JUNGERMANNIALES

LOPHOZIACEAE

Barbilophozia hatcheri (Evans) Loesk
Orthocaulis floerkii (Web. & Mohr) Buch
Lophozia sp.

MARSUPELLACEAE

Gymnomitrium varians (Lindb.) Schiffn.

SCAPANIACEAE

Scapania irrigua (Nees.) Dum.

APPENDIX I. (cont'd.)

PTILIDIACEAE

Ptilidium pulcherrimum (Web.) Hamp.

MARCHANTIALES

MARCHANTIACEAE

Preissia quadrata (Scop.) Nees

PTERIDOPHYTA

OPHIOGLOSSACEAE

Botrychium simplex E. Hitchc. (?)

POLYPODIACEAE

Cystopteris fragilis (L.) Bernh.

EQUISETACEAE

Equisetum scirpoides Michx.

LYCOPODIACEAE

Lycopodium alpinum L.
L. annotinum L.
L. selago L.
L. sitchense Rupr.

SELAGINELLACEAE

Selaginella densa Rydb.

SPERMATOPHYTA
GYMNOSPERMAE
CONIFERAE

PINACEAE

Abies lasiocarpa (Hook.) Nutt.
Juniperus communis L.
Picea engelmannii Parry
Pinus contorta Loudon var. *latifolia* Engelm.

APPENDIX I. (cont'd.)

ANGIOSPERMAE
MONOCOTYLEDONAE

GRAMINEAE

Agropyron latiglume (Scribn. & Smith) Rydb.
Agrostis variabilis Rydb.
Arctagrostis arundinacea (Trin.) Beal
Calamagrostis inexpansa A. Gray
Deschampsia atropurpurea (Wahlenb.) Scheele
D. caespitosa (L.) Beauv.
Elymus innovatus Beal
Festuca baffinensis Polunin
F. brachyphylla Schultes
Hierochloe alpina (Sw.) R. & S.
Phleum alpinum L.
Poa alpina L.
P. arctica R.Br.
P. epilis Scribn.
P. longipila Nash
Trisetum spicatum (L.) Richt.

CYPERACEAE

Carex albo-nigra Mack.
C. atrosquama Mack.
D. drummondiana Dewey
C. macrochaeta C.A. Mey.
C. microglochin Wahlenb.
C. nardina Fries
C. nardina var. *hepburnii* (Boott) Kükenth.
C. nigricans C.A. Mey.
C. petricosa Dewey
C. phaeocephala Piper
C. scirpiformis Mack.
C. scirpoidea Michx.
C. spectabilis Dewey
Eriophorum scheuchzeri Hoppe
Kobresia bellardii (All.) Degl.

JUNCACEAE

Juncus biglumis L.
J. castaneus Sm.
J. drummondii E. Meyer
Luzula arcuata(Wahl.) Wahl.
L. parviflora (Ehrh.) Desv. (?)
L. spicata (L.) DC.
L. wahlenbergii Rupr.

APPENDIX I. (cont'd.)

LILIACEAE

Tofieldia pusilla (Michx.) Pers.
Zygadenus elegans Pursh

DICOTYLEDONAE

SALICACEAE

Salix alaxensis (Anderss.) Coville
S. arctica Pall.
S. nivalis Hook.
S. vestita Pursh.

BETULACEAE

Betula glandulosa Michx.

POLYGONACEAE

Oxyria digyna (L.) Hill
Polygonum viviparum L.

PORTULACACEAE

Claytonia lanceolata Pursh

CARYOPHYLLACEAE

Arenaria rossii R. Br.
A. sajanensis Willd.
Cerastium beeringianum Cham. & Schlecht.
Silene acaulis L. var. *exscapa* (All.) DC.
S. acaulis var. *exscapa* forma *albiflora* Porsild
Stellaria calycantha (Ledeb.) Bong.
S. monantha Hultén

RANUNCULACEAE

Anemone drummondii S. Wats.
A. parviflora Michx.
Aquilegia flavescens S. Wats.
Caltha leptosepala DC.
Ranunculus eschscholtzii Schlecht.
R. gelidus Kar. & Kir.
R. nivalis L.
R. pygmaeus Wahlenb.
Trollius albiflorus (A. Gray) Rydb.

APPENDIX I. (cont'd.)

CRUCIFERAE

Arabis drummondii A. Gray
Cardamine bellidifolia L.
Draba crassifolia R. Grah.
D. incerta Payson
D. nivalis Liljebl. var. *elongata* S. Wats.
D. paysonii Macbr. var. *treleasii* (Schulz) C.L. Hitchc.

CRASSULACEAE

Sedum stenopetalum Pursh

SAXIFRAGACEAE

Parnassia fimbriata Konig
Saxifraga adscendens L.
S. aestivalis Fisch. & Mey.
S. bronchialis L.
S. caespitosa L.
S. cernua L.
S. oppositifolia L.
S. rhomboidea Greene
S. rivularis L.

ROSACEAE

Dryas hookeriana Juz.
Potentilla diversifolia Lehm.
P. fruticosa L.
P. hyparctica Malte
P. nivea L.
P. villosa Pallas ex Pursh
Sibbaldia procumbens L.

LEGUMINOSAE

Astragalus alpinus L.
Hedysarum alpinum L.
Oxytropis campestris (L.) DC. var. *cusickii* (Greene) Barn.
O. podocarpa A. Gray

EMPETRACEAE

Empetrum nigrum L.

ONAGRACEAE

Epilobium alpinum L.
E. latifolium L.

APPENDIX I. (cont'd.)

PYROLACEAE

Moneses uniflora (L.) A. Grlay
Pyrola grandiflora Radius
P. minor L.
P. secunda L.

ERICACEAE

Arctostaphylos rubra (Rehder & Wils.) Fern.
A. uva-ursi (L.) Spreng.
Cassiope mertensiana (Bong.) D. Don
C. tetragona (L.) ssp. *saximontana* (Small) Porsild
Kalmia polifolia Wang. var. *microphylla* (Hook.) Rehd.
Ledum groenlandicum Oeder
Phyllodoce empetriformis (Smith) D. Don
P. glanduliflora (Hook.) Coville
x *P. intermedia* (Hook.) Camp
Vaccinium scoparium Leiberg
V. vitis-idaea L. var. *minus* Lodd.

PRIMULACEAE

Androsace septentrionalis L. var. *subumbellata* A. Nels.

GENTIANACEAE

Gentiana glauca Pallas
G. prostrata Haenke var. *americana* Engelm.
Gentianella propinqua (Richards.) J.M. Gillett

BORAGINACEAE

Myosotis alpestris Schmidt

SCROPHULARIACEAE

Castilleja miniata Dougl.
C. occidentalis Torr.
Pedicularis bracteosa Benth.
P. capitata Adams
P. flammea L.
P. lanata Cham. & Schlecht.
Pedicularis oederi L.
Veronica alpina L. var. *unalaschensis* C.& S.

CAMPANULACEAE

Campanula lasiocarpa Cham.
C. uniflora L.

APPENDIX I. (cont'd.)

COMPOSITAE

Agoseris aurantiaca (Hook.) Greene
Antennaria alpina (L.) Gaertn. var. *media* (Greene) Jepson
A. monocephala DC. (?)
A. lanata (Hook.) Greene
Arnica alpina (L.) Olin
A. latifolia Bong
Artemisia norvegica Fries
Aster sibiricus L.
Crepis nana Richards.
Erigeron acris L. var. *debilis* A. Gray
E. compositus Pursh
E. compositus var. *glabratus* Macoun
E. humilis Grah.
E. peregrinus (Pursh) Greene ssp. *callianthemus* (Greene) Cronq.
Hieracium gracile Hook.
Petasites frigidus (L.) Fries var. *nivalis* (Greene) Cronq.
Saussurea densa (Hook.) Rydb.
Senecio cymbalarioides Nutt.
S. pauciflorus Pursh
S. triangularis Hook.
Solidago multiradiata Ait.
Taraxacum lyratum (Ledeb.) DC.

APPENDIX II. DAILY METEOROLOGICAL DATA ON SIGNAL MOUNTAIN DURING THE SUMMER OF 1967.

MONTH	DAY	HOURS OF DAYLIGHT	SOLAR RADIATION IN LY	TOTAL MILES OF WIND (8 A.M. - 8 P.M.)	TOTAL KM OF WIND	MEAN WIND VELOCITY IN M P H	MEAN WIND VELOCITY IN KM/HR	MAXIMUM TEMP. IN °F.	MINIMUM TEMP. IN °F.	MAXIMUM % RELATIVE HUMIDITY	MINIMUM % R.H.	PRECIPITATION IN MM
June	23	16:55	756	-*	-	-	-	72	29	73	40	
	24	:55	810	155	250	6.5	10.5	64	40	74	41	
	25	:55	540	144	230	6.0	9.7	68	46	60	47	
	26	:54	594	-	-	-	-	61	40	62	42	
	27	:54	-	-	-	-	-	53	34	100	45	
	28	:53	198	-	-	-	-	52	36	100	63	0.3
	29	:52	468	-	-	-	-	48	33	100	35	
	30	16:51	774	-	-	-	-	50	30	80	42	
1 WEEK												
TOTAL			4140	1293	2081							0.3
MEAN			591	185	297	7.7	12.8	59	36	81	44	
July	1	16:50	711	190	306	7.9	12.7	63	32	80	25	
	2	:49	837	106	171	4.4	7.1	68	37	69	26	
	3	:48	684	141	227	5.9	9.5	66	44	-	20	
	4	:47	342	163	262	6.8	10.9	50	43	100	49	2.34
	5	:45	477	100	161	4.2	6.8	52	35	93	41	
	6	:44	324	170	274	7.1	11.4	45	36	100	54	0.38
	7	:42	198	122	196	5.1	8.2	44	35	80	58	
	8	:40	342	176	283	7.3	11.7	44	33	100	70	3.81
	9	:38	405	152	245	6.3	10.1	45	26	98	57	
	10	:37	576	104	167	4.3	6.9	56	31	76	41	
	11	:35	675	177	285	7.4	11.9	65	41	59	28	
	12	:33	675	166	267	6.9	11.1	71	48	50	21	
	13	:31	522	153	246	6.4	10.3	61	41	90	45	1.27
	14	:28	675	90	145	3.7	6.0	60	41	88	36	0.76
	15	:25	693	91	146	3.8	6.1	66	42	69	29	
	16	:23	729	161	259	6.7	10.8	69	49	45	29	
	17	:21	585	157	253	6.5	10.5	64	48	46	25	
	18	:18	567	118	190	4.9	7.9	56	41	64	30	
	19	:16	405	107	172	4.5	7.2	51	38	98	50	Tr.
	20	:13	360	159	256	6.6	10.6	49	33	100	68	3.81
	21	:10	297	107	172	4.5	7.2	42	29	100	77	24.13
	22	:07	513	104	167	4.3	6.9	49	32	80	60	0.51
	23	:04	342	145	233	6.0	9.7	55	41	66	50	
	24	16:02	297	162	261	6.7	10.9	50	42	98	55	
	25	15:59	684	132	212	5.5	8.9	57	35	84	38	4.45

APPENDIX II. Cont'd.

MONTH DAY	DAYLIGHT HRS.	INSOLATION	MILES OF WIND	KM OF WIND	MEAN WIND IN M P.H	MEAN WIND IN KM/HR	MAX. TEMP.	MIN. TEMP.	MAX. R.H.	MIN. R.H.	PRECIP. IN MM
July 26	15:56	540	64	103	2.7	4.3	60	44	52	40	Tr.
27	:53	513	111	179	4.6	7.4	64	49	56	29	Tr.
28	:49	639	166	267	6.9	11.1	64	52	48	20	
29	:46	666	132	212	5.5	8.9	63	45	56	28	
30	:43	378	160	257	6.7	10.8	54	46	96	42	2.03
31	15:40	405	128	206	5.3	8.5	43	33	96	51	Tr.
JULY TOTAL		16,056	4214	6782							41.49
MEAN		518	136	219	5.7	9.2	56	44	78	42	
Aug. 1	15:37	495	141	227	5.9	9.5	54	36	78	39	
2	:33	612	85	137	3.5	5.6	66	39	74	34	
3	:30	630	120	193	5.0	8.0	63	39	56	28	
4	:27	540	177	285	7.4	11.9	63	44	100	42	0.25
5	:23	450	233	375	9.7	15.6	54	40	97	65	1.02
6	:19	468	87	140	3.6	5.8	58	39	96	44	0.03
7	:16	270	88	142	3.7	6.0	47	38	98	70	0.51
8	:12	270	130	209	5.4	8.7	52	39	95	68	6.48
9	:08	630	105	169	4.4	7.1	64	44	73	42	
10	:05	657	219	352	9.1	14.6	69	50	53	26	
11	15:01	468	230	370	9.6	15.4	64	53	63	33	Tr.
12	14:57	423	168	270	7.0	11.3	62	49	59	40	0.03
13	:54	675	162	261	6.7	10.9	62	49	57	30	
14	:50	675	157	253	6.5	10.5	68	48	56	31	
15	:46	648	120	193	5.0	8.0	69	51	46	26	
16	:42	657	118	190	4.9	7.9	72	50	47	24	
17	:38	540	73	117	3.0	4.8	71	49	63	28	
18	:35	558	177	285	7.4	11.9	75	56	43	25	
19	:31	567	98	157	4.1	6.6	71	50	55	28	
20	:27	495	182	293	7.6	12.2	69	55	42	21	
21	:23	198	93	150	3.9	6.3	51	43	99	42	
22	:19	225	130	209	5.4	8.7	54	39	99	37	
23	:15	297	167	269	7.0	11.3	47	34	100	47	0.77
24	:11	288	164	264	6.8	10.9	46	30	100	38	Tr.
25	:07	603	112	180	4.7	7.6	58	31	66	24	
26	:03	603	259	417	10.8	17.4	68	39	37	21	
27	14:01	513	208	335	8.7	14.0	65	50	51	30	
28	13:55	522	77	124	3.2	5.1	67	43	89	34	0.03
29	:51	522	103	166	4.3	6.9	69	47	74	29	
30	:47	522	135	217	5.6	9.0	71	48	69	23	
31	13:43	495	195	314	8.1	13.0	73	54	40	24	
AUGUST TOTAL		15,516	4513	7263							9.12
MEAN		501	146	234	6.1	9.8	64	44	70	35	

APPENDIX II. Cont'd.

MONTH DAY	DAYLIGHT HRS.	INSOLATION	MILES OF WIND	KM OF WIND	MEAN WIND IN M P H	MEAN WIND IN KM/HR	MAX. TEMP.	MIN. TEMP.	MAX. R.H.	MIN. R.H.	PRECIP. IN MM
Sept. 1	13:39	387	242	389	10.1	16.3	68	53	100	26	4.06
2	:35	180	210	338	8.7	14.1	48	32	98	46	0.03
3	:31	252	210	338	8.7	10.1	55	40	70	40	Tr.
4	13:27	432	152	244	6.3	12.6	61	44	62	-	

* No data

APPENDIX III. TEMPERATURE DATA AT SEVERAL LEVELS ABOVE AND BELOW THE GROUND SURFACE.

DATE		MAXIMUM TEMPERATURE IN °F.					MINIMUM TEMPERATURE IN °F.				
		135 cm ABOVE	50 cm ABOVE	18 cm ABOVE	2 cm BELOW	10 cm BELOW	135 cm ABOVE	50 cm ABOVE	18 cm ABOVE	2 cm BELOW	10 cm BELOW
July	1	56	63	60	62	52	-	32	32	32	-
	2	60	68	63	66	56	40	37	37	37	40
	3	63	66	66	-	56	45	44	43	40	43
	4	48	50	50	52	47	44	43	43	37	44
	5	50	52	52	55	49	36	35	35	36	40
	6	42	44	44	44	43	32	36	34	37	39
	7	41	44	44	41	40	36	35	35	33	38
	8	42	44	43	46	42	33	33	33	35	37
	9	36	35	38	38	38	28	26	26	32	35
	10	50	56	51	51	42	33	31	31	31	33
	11	58	66	65	-	54	42	41	40	35	37
	12	68	71	71	68	58	49	48	48	44	44
	13	60	61	62	62	53	48	47	47	42	46
	14	58	60	61	65	56	44	42	42	40	43
	15	64	66	66	68	59	46	42	42	40	44
	16	66	69	69	69	59	51	49	49	44	46
	17	61	64	65	62	58	52	48	50	45	47
	18	53	56	56	59	54	44	41	41	41	45
	19	51	51	51	59	51	38	38	38	41	44
	20	47	49	48	54	58	37	38	37	40	43
	21	44	42	41	39	44	32	29	30	34	38
	22	47	49	48	50	45	37	36	35	33	36
	23	53	55	55	51	47	42	41	41	37	40
	24	50	50	-	50	46	43	43	43	40	41
	25	56	57	57	61	53	36	35	35	33	36
	26	58	61	60	57	52	46	44	44	39	42
	27	63	65	64	61	55	51	49	49	43	47
	28	61	64	64	63	58	53	52	51	44	46
	29	61	64	63	69	60	48	45	45	42	45
	30	52	54	54	55	52	48	46	46	44	46
	31	40	44	43	45	44	34	33	33	36	40
MEAN		53.5	56.4	55.5	56.0	51.0	41.6	40.0	40.0	39.0	41.5

APPENDIX III. Cont'd.

DATE		MAXIMUM TEMPERATURE IN °F. 135 cm ABOVE	50 cm ABOVE	18 cm ABOVE	2 cm BELOW	10 cm BELOW	MINIMUM TEMPERATURE IN °F. 135 cm ABOVE	50 cm ABOVE	18 cm ABOVE	2 cm BELOW	10 cm BELOW
Aug.	1	52	54	54	52	48	36	36	35	34	37
	2	59	66	61	64	58	40	39	38	36	40
	3	63	63	66	69	60	46	39	43	40	43
	4	63	63	63	71	61	46	44	44	43	45
	5	52	54	55	62	55	41	40	40	41	45
	6	56	58	58	63	56	41	39	39	40	44
	7	46	47	47	52	48	39	38	40	41	43
	8	48	52	50	48	47	41	39	39	40	42
	9	61	64	63	62	56	45	44	44	41	43
	10	65	69	69	65	59	50	50	50	42	45
	11	62	64	61	59	55	53	53	52	44	46
	12	62	62	63	62	57	50	49	48	44	--
	13	65	62	67	67	61	53	49	49	46	48
	14	62	68	68	66	61	52	48	48	47	49
	15	66	69	69	68	62	52	51	50	46	48
	16	68	72	72	71	64	52	50	50	45	48
	17	70	71	70	69	63	53	49	49	46	49
	18	71	75	75	73	66	57	56	55	48	51
	19	68	71	71	72	66	52	50	49	47	50
	20	66	69	70	67	62	55	55	54	50	52
	21	50	51	52	56	52	42	43	43	46	49
	22	52	54	54	56	53	38	39	38	40	44
	23	43	47	47	49	47	40	34	39	39	43
	24	43	46	47	49	47	30	30	30	34	39
	25	52	58	56	58	53	33	31	30	32	37
	26	64	68	68	65	58	44	39	40	40	42
	27	61	65	65	64	58	51	50	50	44	48
	28	62	67	66	66	60	45	43	44	43	46
	29	66	69	67	70	64	48	47	46	44	46
	30	68	71	71	69	62	51	48	48	45	47
	31	70	73	73	68	62	55	54	54	48	50
MEAN		60	62.5	62.5	63	57.5	46	44.4	44.5	42.5	45.3

APPENDIX III. Cont'd.

DATE	MAXIMUM TEMPERATURE IN °F. 135 cm ABOVE	50 cm ABOVE	18 cm ABOVE	2 cm BELOW	10 cm BELOW	MINIMUM TEMPERATURE IN °F. 135 cm ABOVE	50 cm ABOVE	18 cm ABOVE	2 cm BELOW	10 cm BELOW
Sept. 1	66	68	67	64	60	58	53	58	51	52
2	46	48	48	47	48	36	32	36	40	—
3	—	55	55	54	51	42	40	41	39	42
4	61	61	60	57	53	—	44	44	41	44

APPENDIX IV. MAXIMUM AIR TEMPERATURES IN °F. AT MICROENVIRONMENTAL STATIONS ON SIGNAL MOUNTAIN.

	MICROENVIRONMENTAL STATION								
DATES	M	1	2	3	4	5	6	7	8
July 2-4	66	74	77	73	67	72	72	-	61
4-6	52	53	62	61	58	58	55	-	48
6-9	44	43	51	48	46	51	48	-	52
9-10	51	57	57	56	55	56	56	-	55
10-12	65	69	73	73	72	69	73	76	62
12-14	71	73	78	75	73	72	73	74	62
14-16	68	72	74	72	71	70	71	74	62
16-17	69	73	75	72	72	75	74	69	62
17-19	64	68	71	67	65	69	66	68	60
19-25	55	56	62	58	56	59	60	61	56
25-28	64	69	72	68	70	67	67	70	62
28-31	63	69	73	70	70	68	70	70	60
MEAN OF JULY READINGS	61.0 (64.9)*	64.7	68.8	66.1	64.6	65.5	65.4	70.3*	58.5
Aug. 1-4	66	71	74	70	70	71	71	69	63
4-8	63	63	74	72	72	65	63	67	62
8-11	69	69	74	71	70	70	70	69	63
11-14	68	70	73	72	70	70	69	72	64
14-18	72	73	80	77	76	75	72	78	68
18-21	75	78	81	78	74	78	78	77	71
21-25	54	57	61	60	58	60	55	58	53
25-28	68	68	74	73	70	70	68	70	63
28-31	71	73	77	78	75	73	72	72	68
MEAN OF AUG. READINGS	67.3	69.1	74.2	72.3	70.5	70.2	68.7	70.2	63.9
Sept. 1-4	73	73	77	78	-	73	71	72	57
MEAN OF SUMMER READINGS	64.1	66.9	71.4	69.2	67.1	67.8	67.0	70.3	60.6

* based on 8 rather than 12 readings

APPENDIX V. MINIMUM AIR TEMPERATURES IN °F. AT MICROENVIRONMENTAL STATIONS ON SIGNAL MOUNTAIN.

DATES	MICROENVIRONMENTAL STATION								
	M	1	2	3	4	5	6	7	8
July 2-4	37	37	37	38	39	33	39	-	38
4-6	35	37	35	35	33	35	35	-	36
6-9	26	29	28	28	26	28	28	-	30
9-10	31	29	30	29	31	30	31	-	31
10-12	41	41	38	39	39	39	37	35	32
12-14	42	42	40	42	40	36	37	37	36
14-16	42	42	38	40	39	33	37	36	35
16-17	48	51	49	48	49	38	44	45	42
17-19	38	39	38	37	37	34	34	32	33
19-25	29	30	29	32	30	29	31	32	33
25-28	44	43	42	43	44	38	40	36	39
28-31	33	32	33	34	32	32	33	33	35
MEAN OF JULY READINGS	37.2 (39.6)*	37.7	36.4	37.1	36.6	33.8	35.5	35.8*	35.0
Aug. 1-4	35	33	34	33	35	32	33	31	32
4-8	39	38	37	37	37	33	35	34	34
8-11	44	50	45	44	44	44	45	43	42
11-14	48	47	48	47	49	47	47	45	45
14-18	49	49	46	46	49	42	42	41	45
18-21	43	43	43	44	42	40	43	43	40
21-25	30	28	28	27	30	23	25	23	25
25-28	40	41	42	41	42	39	39	35	35
28-31	46	44	45	46	47	39	42	40	36
MEAN OF AUG. READINGS	41.6	41.4	40.9	40.6	41.7	37.7	39.0	37.2	37.1
Sept. 1-4	36	37	38	35	-	37	39	39	38
MEAN OF SUMMER READINGS	38.9	39.2	38.3	38.4	38.8	35.5	37.1	36.7	36.0

* based on 8 rather than 12 readings.

APPENDIX VI. SOIL TEMPERATURE READINGS IN °F. AT 10 CM DEPTH AT MICROENVIRONMENTAL STATIONS.

LEGEND: M = thermograph data at major station, from lead buried in bare soil
A = air temperature 18 cm above ground
O = soil temperature under open or unvegetated area
W = water temperature

DATE		M	ME-2			ME-3			ME-4			ME-5			ME-6			ME-7		ME-8		
		O	A	O	V	A	O	V	A	O	V	A	O	V	A	O	V	A	V	A	W	V
July 4/67	4:40 p.m.	45													48	48	41					
	5:30	46																		49	41	41
	5:45	47				51	51	46														
	6:00	47							49	52	44											
	6:20	47	-	56	50																	
	6:30	47										47	38	38								
9	4:50 p.	38										35	--	33								
	5:00	37	38	39	38																	
	5:30	37							35	37	36											
	5:40	37				35	38	38														
	5:50	37																		32	35	35
	6:20	36													34	37	37					
10	1:45 p.	44										54	38	34								
	1:55	45	57	47	43																	
	2:25	45							52	44	42											
	2:40	45				54	45	41														
	2:55	46																		48	44	41
	3:50	46													47	46	40					
12	10:00 a.	48										68	40	40								
	10:30	49	70	50	46																	
	12:45	54							72	50	48											
	1:05	55				72	52	46														
	1:50	56																		59	43	44
	2:10	57																75	44			
	2:50	58													71	52	47					

APPENDIX VI. Cont'd.

DATE		M	ME-2			ME-3			ME-4			ME-5			ME-6			ME-7		ME-8		
		O	A	O	V	A	O	V	A	O	V	A	O	V	A	O	V	A	V	A	W	V
July 14/67	11:20 a.	50										63	43	41								
	12:00	52	64	54	49																	
	1:10 p.	54							55	54	49											
	1:25	54				67	54	47														
	2:20	55																		56	42	42
	2:40	55																64	46			
	3:15	56													62	52	47					
16	12:25 p.	56										70	44	42								
	1:15	57	69	58	54																	
	1:50	58							62	54	52											
	2:10	58				58	58	52														
	3:10	58																		58	42	42
	3:20	58																68	47			
	4:00	58													68	54	57					
17	10:20 a.	50										57	42	43								
	10:50	50	58	52	50																	
	11:08	51							58	49	48											
	11:25	51				63	50	48														
	11:40	52																		55	38	38
	11:50	53																68	45			
	12:35 p.	54													65	52	46					
19	10:30 a.	46										52	41	41								
	10:45	46	52	47	47																	
	11:10	47							50	46	46											
	11:30	48				52	48	46														
	11:45	48																		46	38	38
	11:55	48																59	44			
	12:20 p.	49													57	47	47					
25	10:45 a.	44										54	40	37								
	11:20	45	55	42	40																	
	11:45	46							55	43	40											
	12:30 p.	48				58	45	43														
	1:00	50																		51	43	43
	1:10	50																58	42			
	2:00	51													59	48	43					

APPENDIX VI. Cont'd.

DATE		M	ME-2			ME-3			ME-4			ME-5			ME-6			ME-7		ME-8		
		O	A	O	V	A	O	V	A	O	V	A	O	V	A	O	V	A	V	A	W	V
July 28/67	10:20 a.	50													59	48	46					
	11:00	51																66	46			
	11:10	52																		54	39	39
	11:40	53				63	49	47														
	12:00	54							60	49	49											
	12:45 p.	55	70	54	51																	
	12:55	55										67	48	44								
31	10:20 a.	42										45	41	42								
	10:40	43	49	45	43																	
	11:15	44							40	43	41											
	11:30	44				43	44	43														
	11:45	44																		40	37	37
	12:15 p.	44																46	44			
	12:40	44													42	44	44					
Aug. 4	11:00 a.	50										59	45	44								
	11:15	51	65	51	48																	
	12:00	53							58	49	47											
	12:35 p.	54				68	51	51														
	1:20	57																		58	44	41
	1:30	57																65	46			
	2:15	60													60	54	47					
8	10:20 a.	45										48	44	43								
	10:30	45	49	46	46																	
	10:55	45							47	44	44											
	11:05	45				45	46	46														
	11:15	46																		43	38	38
	11:20	46																48	44			
	11:50	46													47	44	44					
11	10:00 a.	49										63	46	46								
	10:10	50	66	52	50																	
	10:35	50							64	49	49											
	10:50	51				67	51	49														
	11:10	51																		59	40	40
	11:25	52																69	46			
	12:00	53													64	50	47					

APPENDIX VI. Cont'd.

DATE		M	ME-2			ME-3			ME-4			ME-5			ME-6			ME-7		ME-8		
		O	A	O	V	A	O	V	A	O	V	A	O	V	A	O	V	A	V	A	W	V
Aug. 14/67	10:30 a.	51													63	49	49					
	11:05	52																63	48			
	11:15	52																		60	42	40
	11:30	53				64	53	53														
	12:00	54							62	52	52											
	12:20 p.	55	69	58	54																	
	12:50	56										62	47	51								
18	11:00 a.	57													70	50	48					
	11:30	58										75	50	48								
	11:45	59	80	59	56																	
	12:15 p.	60							77	56	56											
	12:30	60				76	59	54														
	1:20	62																74	48			
	1:25	62																		65	50	44
21	11:00 a.	49										52	50	48								
	11:10	50	55	53	53																	
	11:30	50							56	50	52											
	11:40	50				62	52	52														
	11:45	51																		52	41	39
	11:50	51																63	46			
	12:10 p.	52													67	50	50					
25	10:00 a.	39													44	38	40					
	10:20	40																50	40			
	10:30	40																		44	37	34
	2:50 p.	51				60	52	47														
	3:40	52							56	48	46											
	3:55	52	61	51	49																	
	4:00	53										57	44	41								
28	11:00 a.	50													61	45	45					
	11:30	52																69	44			
	11:40	52																		58	42	40
	11:55	53				70	52	50														
	12:30 p.	54							65	52	50											
	12:50	55	67	56	52																	
	12:55	56										65	48	46								

APPENDIX VI. Cont'd.

DATE		M	ME-2			ME-3			ME-4			ME-5			ME-6			ME-7		ME-8		
		O	A	O	V	A	O	V	A	O	V	A	O	V	A	O	V	A	V	A	W	V
Aug. 31/67	9:50 a.	51										66	49	47								
	10:05	52	70	54	53																	
	10:25	52							68	51	53											
	10:50	53				70	54	53														
	12:30 p.	56																		63	44	42
	12:40	56																73	46			
	3:20	62													71	57	50					
Sept. 4	10:00 a.	45	62	47	47																	
	10:30	45										58	44	44								
	1:30 p.	49													58	48	46					
	1:55	50																65	46			
	2:00	50																		54	41	41
	2:50	51				64	52	49														
	3:10	52							62	50	50											

APPENDIX VII. COMPARISON OF TEMPERATURES*, PRECIPITATION AND SOLAR RADIATION DATA AT SIGNAL MOUNTAIN (S) AND TWO VALLEY STATIONS, JASPER (J) AND DEVONA (D) DURING THE SUMMER OF 1967. (- signifies no data)

DATE	MAXIMUM TEMPERATURE			MINIMUM TEMPERATURE			INCHES OF PRECIPITATION			LY SOLAR RADIATION	
	S	J	D	S	J	D	S	J	D	S	D
July 1	56	74	-	-	35	-					
2	60	79	-	40	43	-					
3	63	84	-	45	40	-					
4	48	66	-	44	53	-	0.09	0.07	-		
5	50	68	-	36	46	-		Tr.	-		
6	42	61	-	32	47	-	0.02	0.02	-		
7	41	63	-	36	43	-		0.02	-		
8	42	62	-	33	46	-	0.15	0.09	-		
9	36	60	-	28	42	-		0.05	-		
10	50	71	-	33	37	-					
11	58	83	-	42	40	-					
12	68	88	-	55	46	-		Tr.	-		
13	60	77	-	48	55	-	0.05	0.11	-		
14	58	77	-	44	44	-	0.03		-		
15	64	82	-	46	42	-					
16	66	86	-	51	44	-					
17	61	84	-	52	44	-					
18	53	75	74	44	48	-					
19	51	69	70	38	52	50	Tr.			405	495
20	47	65	65	37	48	52	0.15	0.07	-	360	585
21	44	57	55	32	45	45	0.95	1.09	-	297	360
22	47	66	68	37	40	45	0.02	Tr.	-	513	603
23	53	60	63	42	44	49		0.24	-	342	522
24	50	58	-	43	46	49		0.16	-	297	243
25	56	73	70	36	43	40	0.18			684	360?
26	58	76	74	46	46	46	Tr.			540	360?
27	63	82	80	51	49	56	Tr.	Tr.	Tr.	513	360?
28	61	82	77	53	47	46				639	297?
29	61	78	76	48	42	39				666	171?
30	52	70	66	48	46	42	0.08	0.23	0.27		-
31	40	61	62	34	44	38	Tr.			405	558
TOTAL							1.63	2.15		5661	4914
MEAN	56	73		44	45					472	410

* ACTUAL TEMPERATURES

APPENDIX VII. Cont'd.

DATE	MAXIMUM TEMPERATURE			MINIMUM TEMPERATURE			INCHES OF PRECIPITATION			LY SOLAR RADIATION	
	S	J	D	S	J	D	S	J	D	S	D
Aug. 1	52	70	70	36	40	43				495	603
2	59	76	74	40	39	37				612	657
3	63	81	79	46	40	39				630	747
4	63	77	76	46	43	41	0.01	Tr.	0.03	540	738
5	52	71	68	41	50	49	0.04	Tr.	0.24	450	423
6	56	70	68	41	49	46	Tr.	0.36	0.37		-
7	46	62	60	39	47	49	0.02	0.56	0.18		-
8	48	66	65	41	49	48	0.26	0.08		270	540
9	61	78	75	45	53	51				630	657
10	65	85	85	50	48	50		Tr.		657	630
11	62	83	83	53	48	50	Tr.			468	495
12	62	82	81	50	49	47	Tr.			423	450
13	65	83	82	53	51	46				675	378
14	62	84	82	52	52	49				675	315
15	66	86	84	52	46	48				648	522
16	68	88	86	52	43	40				657	657
17	70	86	82	53	47	50				540	612
18	71	91	91	57	45	42				558	540
19	68	88	87	52	48	45				567	612
20	66	87	83	55	47	46				495	603
21	50	68	67	42	53	52		0.04	0.02		-
22	52	70	69	38	50	49		0.01			-
23	43	63	60	40	40	40	0.03	0.10	0.31		-
24	43	62	61	30	40	41	Tr.	0.01			-
25	52	72	69	33	31	31				603	603
26	64	84	82	44	37	45				603	522
27	61	80	80	51	42	47					-
28	62	82	76	45	48	45	Tr.			522	360
29	66	79	74	48	45	43				522	495
30	68	88	86	51	45	44				522	360
31	70	90	86	55	43	41				495	450
TOTAL							0.36	1.18	1.15	13257	12969
MEAN	63	78	76	43	46	45				552	540
Sept. 1	66	87	83	58	52	51	0.16	Tr.	-		
2	46	69	66	36	50	50	Tr.	0.15	-		
3	-	72	71	42	53	61	Tr.		-		
4	61	80	76	-	43	45					
5	-	82	80	-	54	50		Tr.	-		

APPENDIX VIII. WIND VELOCITY DATA FROM SIGNAL MOUNTAIN DURING THE SUMMER OF 1967.

TIME PERIODS: A = 8 p.m. to 8 a.m.
B = 8 a.m. to 12 noon
C = 12 noon to 4 p.m.
D = 4 p.m. to 8 p.m.

DATE	MEAN WIND SPEED (MPH) A	B	C	D	TOTAL MILES	TOTAL KM	MEAN DAILY MPH	MEAN DAILY KM/HR
July 1	11.4	4.5	5.0	3.8	190	306	7.9	12.7
2	4.0	4.0	5.2	6.5	106	171	4.4	7.1
3	5.6	4.2	7.5	6.8	141	227	5.9	9.5
4	7.1	7.2	6.5	5.8	163	262	6.8	10.9
5	4.4	7.0	1.8	3.0	100	161	4.2	6.8
6	9.0	5.2	5.5	4.8	170	274	7.1	11.4
7	4.9	6.2	5.8	3.8	122	196	5.1	8.2
8	9.8	4.0	4.5	5.2	176	283	7.3	11.7
9	6.8	4.2	6.2	7.2	152	245	6.3	10.1
10	4.2	2.2	6.8	4.2	104	167	4.3	6.9
11	9.5	4.2	5.2	6.2	177	285	7.4	11.9
12	7.1	6.8	6.0	7.5	166	267	6.9	11.1
13	6.0	9.2	6.5	4.5	153	246	6.4	10.3
14	2.4	3.5	6.0	5.8	90	145	3.6	6.0
15	2.7	4.0	5.0	4.8	91	146	3.8	6.1
16	7.0	6.5	5.8	7.0	161	259	6.7	10.8
17	5.7	6.2	8.8	7.2	157	253	6.5	10.5
18	3.7	3.0	9.2	6.2	118	190	4.9	7.9
19	3.6	4.5	5.0	6.5	107	172	4.5	7.2
20	7.9	6.5	5.0	4.5	159	256	6.6	10.6
21	4.0	5.5	5.8	3.5	107	172	4.5	7.2
22	4.2	2.0	6.8	4.5	104	167	4.3	6.9
23	6.2	5.0	4.5	8.0	145	233	6.0	9.7
24	6.8	7.5	5.2	7.2	162	261	6.8	10.9
25	7.1	3.0	3.8	5.0	132	212	5.5	8.9
26	1.8	3.0	4.5	3.0	64	103	2.7	4.3
27	4.2	3.0	5.8	6.5	111	179	4.6	7.4
28	6.1	6.5	8.0	8.8	166	267	6.9	11.1
29	5.7	3.5	6.0	6.2	132	212	5.5	8.9
30	5.1	7.8	7.5	9.5	160	257	6.7	10.8
31	4.6	6.0	7.0	5.2	128	206	5.3	8.5
MEAN	5.8	5.0	5.9	5.8	136	219	5.7	9.2
TOTAL					4218	6782		285.2

APPENDIX VIII. Cont'd.

DATE	MEAN WIND SPEED (MPH) A	B	C	D	TOTAL MILES	TOTAL KM	MEAN DAILY MPH	MEAN DAILY KM/HR
Aug. 1	5.5	3.5	7.2	8.0	141	227	5.9	9.5
2	2.8	2.0	4.0	4.0	85	137	3.5	5.6
3	5.9	3.5	5.2	3.5	120	193	5.0	8.0
4	4.8	4.5	7.2	18.2	177	285	7.4	11.9
5	8.5	10.9	10.9	11.2	233	375	9.7	15.6
6	3.4	2.5	3.8	5.2	87	140	3.6	5.8
7	3.0	5.2	5.0	2.8	88	142	3.7	6.0
8	5.2	5.2	8.0	3.8	130	209	5.4	8.7
9	4.2	3.5	4.8	5.5	105	169	4.4	7.1
10	11.0	8.2	8.5	5.0	219	352	9.1	14.6
11	9.0	6.5	8.5	15.5	230	370	9.6	15.4
12	8.9	4.5	6.0	4.8	168	270	7.0	11.3
13	5.2	5.0	10.2	9.5	162	261	6.8	10.9
14	6.1	5.2	7.5	8.2	157	253	6.5	10.5
15	4.2	4.2	6.2	6.8	120	193	5.0	8.0
16	4.3	4.2	5.8	6.5	118	190	4.9	7.9
17	3.1	3.2	1.8	4.0	73	117	3.0	4.8
18	8.1	5.2	8.8	6.0	177	285	7.4	11.9
19	3.1	2.5	6.5	6.2	98	157	4.1	6.6
20	7.9	4.5	6.8	10.5	182	293	7.6	12.2
21	2.9	6.0	4.8	3.8	93	150	3.9	6.3
22	4.5	8.5	7.0	6.0	130	209	5.4	8.7
23	6.8	6.5	7.5	7.2	167	269	7.0	11.3
24	5.4	4.5	10.0	8.2	164	264	6.8	10.9
25	3.8	6.5	5.8	7.0	112	180	4.7	7.6
26	13.8	9.8	7.5	7.5	259	417	10.8	17.4
27	11.5	4.2	7.2	6.0	208	335	8.7	14.0
28	2.0	2.8	4.5	6.0	77	124	3.2	5.1
29	4.2	2.2	2.8	8.0	103	166	4.3	6.9
30	5.3	7.5	5.0	5.2	135	217	5.6	9.0
31	8.3	9.2	5.8	9.0	195	314	8.1	13.0
MEAN	5.9	5.2	6.5	7.1	146	234	6.1	9.8
TOTAL					4513	7263		
Sept. 1	9.6	10.0	12.2	9.5	242	389	10.1	16.3
2	10.0	7.0	7.0	8.5	210	338	8.8	14.1
3	8.0	6.5	6.0	16.0	210	338	8.8	14.1
4	5.1	5.2	8.8	8.5	152	244	6.3	10.1
5	8.1	9.2	7.0	6.5	188	303	7.8	12.6
MEAN [1-5]	8.2	7.6	8.2	9.8	200	322	8.4	13.5
SUMMER MEAN	6.1	5.4	6.4	6.8	148	237	6.2	10.0
TOTAL					9742	15,657		

APPENDIX IX. SPOT READINGS OF WIND VELOCITY IN 1967 AT MICROENVIRONMENTAL STATIONS ON SIGNAL MOUNTAIN.

DATE	TIME	ME-SITE	AVERAGE MPH	AVERAGE KM/HR	HIGHEST GUST MPH	HIGHEST GUST KM/HR	TOTALIZING ANEMOMETER MEAN MPH	TOTALIZING ANEMOMETER MEAN KM/HR
July 12	10:30 a.m.	2	15	24	28	45	6.8	10.9
	1:00 p.	3	12	19	20	32	6.0	9.7
	12:45 p.	4	15	24	24	39	6.0	9.7
	10:00 a.	5	5	8	11	18	6.8	10.9
	2:50 p.	6	8	13	13	21	6.0	9.7
	2:10 p.	7	7	11	14	23	6.0	9.7
	1:50 p.	8	7	11	18	29	6.0	9.7
July 14	12:00 m.	2	8	13	13	21	6.0	9.7
	1:25 p.	3	14	23	20	32	6.0	9.7
	1:10 p.	4	13	21	19	30	6.0	9.7
	11:20 a.	5	7	11	10	16	3.5	5.6
	3:15 p.	6	5	8	13	21	6.0	9.7
	2:40 p.	7	7	11	10	16	6.0	9.7
	2:20 p.	8	5	8	24	39	6.0	9.7
July 16	1:15 p.	2	17	27	21	33	5.8	9.4
	2:10 p.	3	14	23	24	39	5.8	9.4
	1:50 p.	4	17	27	21	33	5.8	9.4
	12:25 p.	5	5	8	9	14	5.8	9.4
	4:00 p.	6	3	5	5	8	5.8	9.4
	3:20 p.	7	6	10	9	14	5.8	9.4
	3:10 p.	8	5	8	11	18	5.8	9.4
July 17	10:50 a.	2	24	39	30	48	6.2	10.0
	11:25 a.	3	21	34	28	45	6.2	10.0
	11:08 a.	4	24	39	34	55	6.2	10.0
	10:20 a.	5	6	10	10	16	6.2	10.0
	12:35 p.	6	18	29	25	40	8.8	14.1
	11:50 a.	7	10	16	18	29	6.2	10.0
	11:40 a.	8	8	13	21	33	6.2	10.0
July 19	10:45 a.	2	15	24	18	29	4.5	7.2
	11:30 a.	3	8	13	11	18	4.5	7.2
	11:10 a.	4	8	13	16	25	4.5	7.2
	10:30 a.	5	4	6	6	10	4.5	7.2
	12:20 p.	6	6	10	13	21	5.0	8.0
	11:55 a.	7	5	8	10	16	4.5	7.2
	11:45 a.	8	5	8	9	14	4.5	7.2
July 25	11:20 a.	2	2	3	8	13	3.0	4.8
	12:30 p.	3	3	5	7	11	3.8	6.0
	11:45 a.	4	2	3	5	8	3.0	4.8
	10:45 a.	5	2	3	4	6	3.0	4.8
	2:00 p.	6	0	0	3	5	3.8	6.0
	1:10 p.	7	2	3	4	6	3.8	6.0
	1:00 p.	8	0	0	4	6	3.8	6.0

APPENDIX IX. Cont'd.

DATE	TIME	ME-SITE	AVERAGE MPH	AVERAGE KM/HR	HIGHEST GUST MPH	HIGHEST GUST KM/HR	TOTALIZING ANEMOMETER MEAN MPH	TOTALIZING ANEMOMETER MEAN KM/HR
July 28	12:45 p.	2	33	53	45	72	8.0	12.9
	11:40 a.	3	20	32	28	45	6.5	10.5
	12:00 m.	4	24	39	30	48	8.0	12.9
	12:55 p.	5	10	16	16	26	8.0	12.9
	10:20 a.	6	11	18	18	29	6.5	10.5
	11:00 a.	7	11	18	16	26	6.5	10.5
	11:10 a.	8	11	18	19	30	6.5	10.5
July 31	10:40 a.	2	12	19	15	24	6.0	9.7
	11:30 a.	3	13	21	18	29	6.0	9.7
	11:15 a.	4	18	29	20	32	6.0	9.7
	10:20 a.	5	5	8	10	16	6.0	9.7
	12:40 p.	6	8	13	13	21	7.0	11.3
	12:15 p.	7	5	8	8	13	7.0	11.3
	11:45 a.	8	0	0	4	6	6.0	9.7
Aug. 4	11:15 a.	2	3	5	5	8	4.5	7.2
	12:30 p.	3	0	0	5	8	7.2	11.5
	12:00 m.	4	3	5	5	8	7.2	11.5
	11:00 a.	5	2	3	4	8	4.5	7.2
	2:15 p.	6	5	8	9	14	7.2	11.5
	1:30 p.	7	5	8	9	14	7.2	11.5
	1:20 p.	8	0	0	3	5	7.2	11.5
Aug. 8	10:30 a.	2	13	21	15	24	5.2	8.4
	11:05 a.	3	9	14	13	21	5.2	8.4
	10:55 a.	4	8	13	10	16	5.2	8.4
	10:20 a.	5	5	8	8	13	5.2	8.4
	11:50 a.	6	7	11	10	16	8.0	12.9
	11:15 a.	7	4	6	7	11	5.2	8.4
	11:20 a.	8	1	2	3	5	5.2	8.4
Aug. 11	10:10 a.	2	23	37	35	56	6.5	10.5
	10:50 a.	3	14	23	22	35	6.5	10.5
	10:35 a.	4	24	39	34	55	6.5	10.5
	10:00 a.	5	7	11	12	19	6.5	10.5
	12:00 m.	6	6	10	10	16	8.5	13.7
	11:25 a.	7	9	14	18	29	6.5	10.5
	11:10 a.	8	11	18	24	39	6.5	10.5
Aug. 14	12:20 p.	2	8	13	12	19	7.5	12.1
	11:30 a.	3	3	5	7	11	5.2	8.3
	12:00 m.	4	9	14	12	19	7.5	12.1
	12:50 p.	5	4	6	6	10	7.5	12.1
	10:30 a.	6	5	8	8	13	5.2	8.3
	11:05 a.	7	2	3	4	6	5.2	8.3
	11:15 a.	8	2	3	3	5	5.2	8.3

APPENDIX IX. Cont'd.

DATE	TIME	ME-SITE	AVERAGE MPH	AVERAGE KM/HR	HIGHEST GUST MPH	HIGHEST GUST KM/HR	TOTALIZING ANEMOMETER MEAN MPH	TOTALIZING ANEMOMETER MEAN KM/HR
Aug. 18	11:45 a.	2	8	13	12	19	8.8	14.1
	12:30 p.	3	8	13	10	16	8.8	14.1
	12:15 p.	4	10	16	12	19	8.8	14.1
	11:30 a.	5	1	2	3	5	6.0	9.7
	11:00 a.	6	2	3	6	10	6.0	9.7
	1:20 p.	7	0	0	3	5	8.8	14.1
	1:25 p.	8	2	3	4	6	8.8	14.1
Aug. 21	11:10 a.	2	10	16	14	23	6.0	9.7
	11:40 a.	3	6	10	10	16	6.0	9.7
	11:30 a.	4	8	13	13	21	6.0	9.7
	11:00 a.	5	2	3	4	6	6.0	9.7
	12:10 p.	6	4	6	6	10	4.8	7.8
	11:55 a.	7	3	5	5	8	4.8	7.8
	11:50 a.	8	4	6	6	10	4.8	7.8
Aug. 25	3:55 p.	2	10	16	15	24	5.8	9.4
	2:50 p.	3	10	16	14	23	5.8	9.4
	3:40 p.	4	8	13	10	16	5.8	9.4
	4:00 p.	5	0	0	4	6	5.8	9.4
	10:00 a.	6	0	0	3	5	6.5	10.5
	10:20 a.	7	2	3	4	6	6.5	10.5
	10:30 a.	8	0	0	2	3	6.5	10.5
Aug. 28	12:50 p.	2	5	8	7	11	4.5	7.2
	11:55 a.	3	2	3	5	8	4.5	7.2
	12:30 p.	4	6	10	8	13	4.5	7.2
	12:55 p.	5	0	0	3	5	4.5	7.2
	11:00 a.	6	2	3	4	6	2.8	4.2
	11:30 a.	7	2	3	5	8	2.8	4.5
	11:40 a.	8	2	3	4	6	2.8	4.5
Aug. 31	10:05 a.	2	11	18	15	29	9.2	14.8
	10:50 a.	3	8	13	10	16	9.2	14.8
	10:25 a.	4	11	18	13	21	9.2	14.8
	9:50 a.	5	0	0	4	6	9.2	14.8
	3:20 p.	6	7	11	13	21	5.8	9.4
	12:40 p.	7	4	6	6	10	5.8	9.4
	12:30 p.	8	7	11	14	23	5.8	9.4
Sept. 4	10:00 a.	2	15	24	22	35	5.2	8.3
	2:50 p.	3	10	16	16	26	8.8	14.1
	3:10 p.	4	15	24	29	47	8.8	14.1
	2:50 p.	5	10	16	16	26	8.8	14.1
	1:30 p.	6	10	16	14	23	8.8	14.1
	1:55 p.	7	9	14	13	21	8.8	14.1
	2:00 p.	8	10	16	16	26	8.8	14.1